

ial

Issues in Applied Linguistics

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SPECIAL ISSUE

NEUROBIOLOGY OF LANGUAGE

John H. Schumann, Guest Editor

MAIN ARTICLES

Beyond Broca's and Wernicke's Areas: An Alternative View on Neurobiology of Language

Lawrence Lem

Procedural Linguistic Skill Acquisition: A Neurobiological Model

Scarlett Robbins

From Input to Intake: Towards a Brain-Based Perspective of Selective Attention

Edynn Sato and Bob Jacobs

Towards a Model of Language Attrition: Neurobiological and Psychological Contributions

Asako Yoshitomi

EXCHANGE

Connectionism: Explanation or Implementation

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Reviews by

Eduardo Faingold, Charlene Polio, James Purpura, Howard Williams

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CONTENTS

EDITORIAL

- On Neurons and Other Embarkations
Joseph R. Plummer 203

GUEST EDITORIAL

- Exploring Neurobiology of Language
John H. Schumann 209

MAIN ARTICLES

- Beyond Broca's and Wernicke's Areas:
An Alternative View on Neurobiology of Language
Lawrence Lem 213

- Procedural Linguistic Skill Acquisition:
A Neurobiological Model
Scarlett Robbins 235

- From Input to Intake:
Towards a Brain-Based Perspective of Selective Attention
Edynn Sato and Bob Jacobs 267

- Towards a Model of Language Attrition:
Neurobiological and Psychological Contributions
Asako Yoshitomi 293

EXCHANGE

- Connectionism: Explanation or Implementation
Cheryl Fantuzzi 319

REVIEWS

Why More English Instruction Won't Mean Better Grammar

Charles James N. Bailey

Reviewed by Eduardo Faingold

341

An Introduction to Second Language Acquisition Research

Diane Larsen-Freeman and Michael H. Long

Reviewed by Charlene G. Polio

344

Communication Strategies: A Psychological Analysis of Second-Language Use

Ellen Bialystok

Reviewed by James Purpura

348

Syntax: A Functional-Typological Introduction II

Talmy Givon

Reviewed by Howard Williams

354

Announcements

366

Publications Received

367

Subscription Information

371

Back Issue Information

373

Information for Contributors

375

On Neurons and Other Embarkations

1

Lull'd in the countless chambers of the brain,
Our thoughts are link'd by many a hidden chain.
Awake but one, and lo! what myriads rise!
Each stamps its image as the other flies.

Samuel Rogers
Pleasures of Memory

Questioners in applied linguistics often ask what and why. Less frequently, questions of when and who arise. This edition of *Issues in Applied Linguistics* is devoted to questions of how and where. How the brain processes, acquires, and uses language have long been inflammatory questions. This flammability seems to hinge more upon the qualities of language than upon whether language is, need be, or ought to be reducible to its mechanistic underpinnings. While the latter methodological issues are indeed controversial, without asking and answering the former questions they seem moot points. It is difficult to know how to answer those who feel language can be significantly studied wholly independent from the brain, since brains seem to be at least minimally essential for its genesis. Once extant, however, why is there a need to study the brain at all? Can't we merely study linguistic processes *per se*, assuming that as we do so we will be illuminating the mind?

The writers published here, I believe, and certainly the editors, are of the opinion that mind *is* brain for most meaningful situations; that is, that the theoretical construct *mind* has little value in the formulation of hypotheses about language and its mechanistic underpinnings. The emphasis throughout this issue is, therefore, on alternatives to current neurobiological, psychological, and philosophical views on language and brain.

Most of the research on brain and language has involved neurolinguistic aphasiology, the study of language abnormalities in

adults whose language faculties have been disrupted as a result of brain injury of one kind or another. This area of research has a crucial place in history and an assured future. Indeed, most of what is currently known about language in the brain comes from studies of this type. Since neural pathology will be a medical fact of life for some time to come, it seems only reasonable to expect this fruitful type of research to continue. However, there is also a need for a different kind of brain research to begin, a kind which focuses on the mechanisms underlying the processes of acquisition, memorization, and forgetting. To this end, John Schumann and several of his students have established the UCLA Neurobiology of Language Research Group (NLRG).

The technique of this group is not necessarily "empirical," although activity of this type is certainly welcome. Due to an acknowledged need in neuroscience for theoretical development on a comprehensive scale, a generation of "Platonic" scientists whose sole function is to review, assimilate, and apply the work of laboratory scientists is being developed. The field is frequently referred to as Theoretical, or Speculative, Neuroscience. The students of the NLRG should be seen within this interdisciplinary light.

Implicit in all that this group discusses within these pages is the awareness that what is being studied is the process of how the brain learns and remembers. To this end, it is frequently necessary to voyage into areas which are ostensibly far afield from traditional linguistics, areas like neurochemistry and neurophysiology.

2

Clay is moulded to make a vessel, but the utility of the vessel lies in the space where there is nothing. . . . Thus, taking advantage of what is, we recognise the utility of what is not.

Lao Tzu
Tao Te Ching

The research interests of the authors represented in this issue of IAL are various. What they have in common is a belief that study of the brain can not only shed light on current issues in the study of

language, it will create as yet undiscovered areas of inquiry. The aim of neurobiological reductionism is not the mere charting of the mechanisms underlying processes linguists have already posited, but the recognition of the spaces "where there is nothing," spaces we would not otherwise realize. With this goal in mind, there is no way that reductionistic, materialistic study of language and its relationship with the brain can be called "naive."

The first article, by Larry Lem, introduces us to one of the key issues facing the brain-language discipline: the potential which linguistically "non-traditional" areas of the brain have for informing continued research. Starting with an explanation of how much of what is currently known about the relationship between brain and language is the result of the historical predominance of a few critical areas for language comprehension and production, Lem goes on to posit alternative brain areas as important to language. This essay is of critical importance because it not only expands the neurobiological field of inquiry, but also forces the issue of how we must look at the brain as a whole if we want to find a language acquisition device.

Much of what we learn about language is not of the type about which learners can talk. There are some forms of linguistic knowledge which are, clearly, implicit. How different or specific types of linguistic knowledge might be differentially represented, acquired, and stored within the brain is the topic of our second main article. Scarlett Robbins, the assistant editor of this journal, has written a piece in which she demonstrates how procedural knowledge might be housed in the brain.

The third main article, by Edynn Sato and Bob Jacobs, focuses on the brain mechanisms necessary for the processes of selective attention. The necessity of this type of activity for the acquisition of language is obvious. How the brain goes about this activity is a topic which the authors emphasize, clearly showing how neurobiological analysis can be the *a priori* approach to the study of language acquisition mechanisms.

An often overlooked area of the study of language is how we go about forgetting it. Asako Yoshitomi submits a piece showing how the analysis of how-we-forget is just as crucial to our understanding of the representation of language in the brain as the study of how-we-remember. She gives us considerable evidence from psychological and neurobiological studies supporting her model of language attrition.

In our last issue, we published an article by Yasuhiro Shirai on Connectionism, a methodological and conceptual schema through which language transfer could be explained. In our *Exchange* section, Cheryl Fantuzzi criticizes many of the premises of Shirai's arguments and questions cognitive modeling in general.

We are fortunate to have four reviews to offer in this issue. Eduardo Faingold reviews a book called "Why More English Instruction Won't Mean Better Grammar." Charlene Polio comments upon the state of the field of applied linguistics in her review of Larsen-Freeman & Long's *Introduction to Second Language Acquisition*. Jim Purpura, the advertising manager of *IAL*, reviews Ellen Bialystok's book, *Communication Strategies: A Psychological Analysis of Second-Language Use*, which posits a new psychological framework to account for language learners' production strategies. And Howard Williams critiques the second volume of Talmy Givon's recent work on morphology and syntax.

3

In creating, the only hard thing's to begin;
A grass-blade's no easier to make than an oak.

James Russell Lowell
A Fable for Critics

Il n'y a que le premier pas qui coute.

[It is only the first step which takes the effort.]

(This quote refers to the legend of Saint Denis who walked away from his own execution carrying his head)

Madame Marie Vichy-Deffand
Lettre à d'Alembert

A little over a year ago, I began working on this journal in the capacity of production assistant. It was the type of beginning which, at the time, seemed reasonably sound and safe: a little work, learn the ropes, and, with luck and years of dedication, be allowed a position among the senior editors. Little did I know. This publication is, I need not remind the reader, a production of graduate students. As students' lives progress, they frequently feel the need

for certain changes as a result of minor hurdles inherent in the path to academic advancement. As a result, within my first year at IAL I moved (rather quickly) through the position of managing editor to the position I now have the very real honor of holding. I thank the former editor, Sally Jacoby, and the former managing editor, Patrick Gonzales, for their support and mentorship. I also thank those who judged me capable of assuming this position, including Marianne Celce-Murcia and John Schumann, whose continued support will never be forgotten.

This third issue with which I am involved happens, quite coincidentally I assure you, to be one which is quite close to my heart. As a member of the NLRG, I have been intimately acquainted with the development of this particular issue. The idea of a second guest-edited issue occurred as a result of our first guest-edited issue of one year ago. The response to that issue was (and continues to be) so enthusiastic that we have decided to continue the practice of thematically focused issues. John Schumann mentioned to Sally Jacoby that there was a body of papers written for his courses that might make an interesting journal issue. One year later, here we are.

Also, this issue of IAL is the first in which none of the current editorial staff or their assistants can say they were around when the idea of founding a journal focusing on the important arguments in our field was conceived. We new folk hope that in the ensuing years we may continue to foster the idea, to continue to uphold the commitment to excellence of the material which goes between these covers, and to institutionalize *Issues in Applied Linguistics* as one of the most eminent journals in the field. To this latter end, I am pleased to announce a European distributor for the journal, subscriptions on six continents, and the assemblage of a new, enthusiastic editorial board with a great many talented people interested in assisting. The future of this journal looks very bright indeed.

I would like to thank the readers of the articles for this issue who gave of their time and expertise to help make these papers accurate and interesting. I would also like to thank all those who helped to make this issue a reality, including the other members of the editorial committee and the production assistants. Most of all I would like to thank the guest editor, John Schumann, without whose helpful guidance and stalwart vision this thematic issue would not be.

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Joseph R. Plummer is a graduate student in the Department of TESL & Applied Linguistics at UCLA. He holds a B.A. in English and American Literature from the University of Massachusetts at Boston. His research interests include neurobiology of language, second language acquisition, and semiotic theory.

Guest Editorial

Exploring Neurobiology of Language

John Schumann

University of California, Los Angeles

Since the mid 1980's, there has been a growing interest in the cognition underlying Second Language Acquisition (SLA). The typical procedure for discovering cognitive processes is to study interlanguage behavior and, on the basis of the patterns observed, to infer causal cognitive mechanisms and processes. This mode of research has produced an interesting set of constructs that includes buffers, filters, analyzers, formulators, conceptualizers, articulators, interpreters, monitors, as well as pidginization, nativization, generalization, simplification, transfer, etc. But there may be another way to understand the mechanisms and processes that are responsible for SLA, and that is by relating SLA to the biological organ responsible for it, the brain. As Bechtel (1992) indicates, constructs such as those above may constitute mechanisms to explain phenomena observed at the behavioral level. But these mechanisms themselves become phenomena to be given mechanistic explanations at the neurobiological level. The reduction often leads to new understanding and perhaps reformulation at the higher level.

At UCLA, one of our doctoral students, Bob Jacobs, began studying neurobiology in 1985. Bob's interest in the relationship between applied linguistic issues and neurobiology led to a series of informal meetings during the fall of 1986 between Professor Arnold Scheibel (Director of the UCLA Brain Research Institute), Professor Wolfgang Klein (Director of the Max Planck Institute in Holland, a visiting professor at the time), Bob, and myself. Using Bob's work (i.e., Jacobs, 1988) as a basis for discussion, we explored a range of issues concerning neurobiology and second language acquisition. These discussions led to a plan to institute a neurobiology course in the Applied Linguistic Program in the

autumn of 1987. The course was taught by Dr. Scheibel and Bob that year and again by Dr. Scheibel in 1989 and 1991. This has resulted in about 30 students who now have a background in neurobiology to which they can refer in their studies of language acquisition, assessment, and use. Our plan is to continue to offer the course every other year as part of our department's program to develop a laboratory system for doctoral training (see Celce-Murcia, 1992). In this regard, we have established the Neurobiology of Language Research Group (NLRG).

With a knowledge of basic neuroanatomy and neurophysiology there are several approaches to the study of cognition in SLA. One can relate interlanguage behavior to parts of the brain that are known to generate similar behaviors. One can also take the mechanisms and processes that have been inferred from SLA studies and match them with neural structures and functions known to operate in similar ways. Finally, one can start with areas of the brain responsible for perception, stimulus appraisal, emotion, attention, and memory, study how they operate, and relate them to SLA. In this way, neurobiology can provide a new perspective on the discipline (see Jacobs and Schumann, 1992).

However, as the members of our department's NLRG have been quick to learn, there is some reluctance in the field to the view that cognitive processes are neural processes and that the study of the brain can inform the study of multilingualism. For example, my earlier work on SLA, the pidginization/accluturation model, was a social-psychological account of SLA that was often criticized for lacking a cognitive component. At a recent conference I presented a neurobiological perspective on cognition in SLA and afterwards I asked a colleague who had been urging me for years to add cognition to the model what she thought. My friend replied, "I said cognitive, not neuro!" I asked, "Well, where do you think cognition takes place?" Being astute in such matters, she replied, "If I don't say the brain, you'll call me a dualist." She was right. Long (1992) has raised the issue of whether it is the applied linguist's job to provide hypotheses about the neurophysiology of language acquisition. I would argue that it is certainly not necessary for applied linguists to undertake such tasks, but if they were to acquire the requisite knowledge, there is no reason why they should not theorize about the neurobiology of language. If the enterprise becomes a productive research paradigm that furthers our understanding of language acquisition and use, it may then be necessary for applied linguists routinely to

learn neurobiology in order to understand and evaluate the explanations that are generated.

Thinking about neurobiology and language has been constrained by the demand that neurobiological accounts address specific, current issues in linguistic theory, such as subadjacency or the empty category principle. When neurobiologists interested in language are unable to do this, linguists usually assert that the problem is that not enough is known about the brain. However, there is a great deal known about the brain, and the problem may be that current linguistic theory is so far off the mark or so abstractly formulated that it defies a neurobiological account. Before a neural explanation of linguistic theory is possible, we may need a much more sophisticated formulation of the theory.

In the articles in this special issue on the brain and language, we have deliberately ignored the constraints referred to above. Instead, we have approached the topic with a very broad view of language. We examine cognitive processes that affect SLA generally (e.g., attention), cognitive processes involved in language production (e.g., procedural knowledge), memory systems affecting language loss (e.g., intermediate memory), and areas of the brain involved in lexical knowledge (e.g., the fusiform cortex).

In these articles, we have not avoided using the relevant neurobiological terms. We feel that expressions such as "the attention areas of the brain" or "the memory centers of the brain," while sparing the reader technical vocabulary, actually are a disservice because they are imprecise and do not allow the reader to know whether the authors are referring to the same or different parts of the anatomy. The articles, therefore, may not be easy reading for someone who is totally naive to the nervous system, but a little study of the included definitions, sketches and diagrams, plus a careful re-reading, should be sufficient for anyone who really wants to grasp the material.

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John H. Schumann is Professor and Chair of the Department of TESL & Applied Linguistics at UCLA. His research interests include the investigation of variable success in second language acquisition from the social psychological, psychological, neurobiological, and linguistic perspectives. He has developed the Acculturation/Pidginization Model for second language acquisition.

Beyond Broca's and Wernicke's Areas: A New Perspective on the Neurobiology of Language

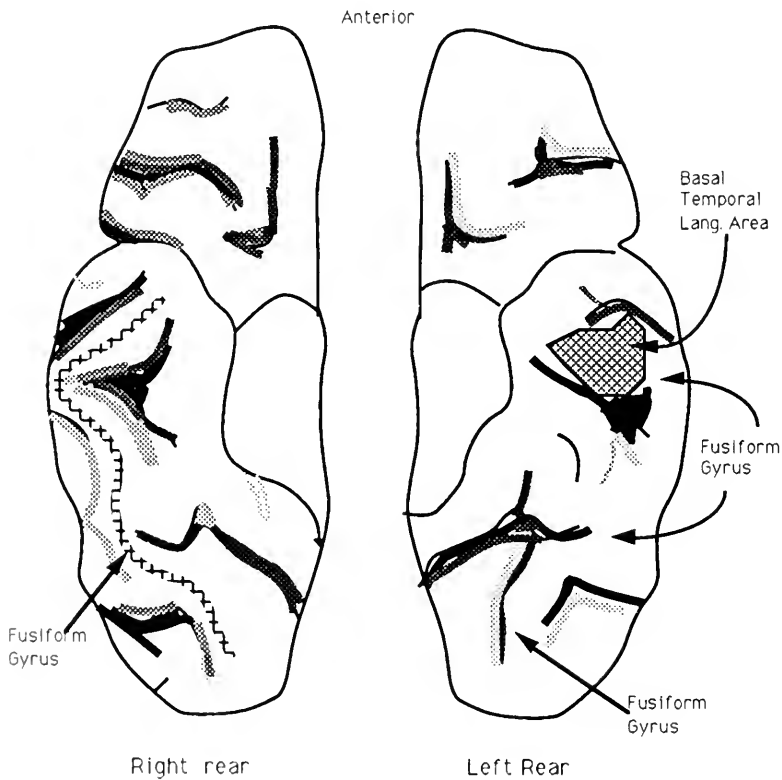
Lawrence Lem
University of California, Los Angeles

Brain-based discussion of language has classically centered around models focused on Broca's and Wernicke's areas. Recent neurobiological research indicates that such models may be oversimplified. The present paper attempts to propose a model in which a far greater number of brain structures are involved in language functions. To demonstrate this model, three areas of the brain rarely associated with language, the anterior cingulate gyrus, the prefrontal cortex, and the basal temporal language area (fusiform gyrus) are examined. Recent neurobiological research linking these areas to language function will be reviewed to illustrate that a whole-brain view of language is both more feasible and better supported by data than the idea of a language-specific brain system, such as the Wernicke-Geschwind model.

INTRODUCTION

Localization theory, which advocates that various abilities are mapped to specific anatomical structures in the brain, was first proposed in the early nineteenth century by Gall and Spurzheim (1810). This theory was applied to language abilities in 1861 when Paul Broca attributed speech to a frontal portion of the brain's left hemisphere, an area that became known as Broca's area. About ten years later, Karl Wernicke correlated a deficit in comprehension and semantic meaning with brain damage in an area of the left temporal lobe now known as Wernicke's area. Wernicke composed a theory of language based on interaction between various sensory areas (such as auditory areas for hearing language) in the brain with Wernicke's and Broca's areas

during language perception and production (Mayeux & Kandel, 1991). Study of the brain and language has continued to focus heavily on these two areas and has produced language theories based on the Wernicke model (Geschwind, 1965; Penfield & Roberts, 1959). In this model, the process of naming a visually sighted object begins by the transfer of information from the eyes to the visual cortex. From there the information is taken to the angular gyrus and then to the adjacent Wernicke's area. Here the visual information becomes a phonetic representation. This representation is sent through the



UNDERSIDE OF THE BRAIN

Figure 1. The diagram of the right side of the brain shows a hatched line that follows the fusiform gyrus down the underside of the brain. The gyrus is pointed out by arrows on the diagram of the left brain. The shaded area indicates the region of the fusiform gyrus known as the basal temporal language area.

arcuate fasciculus to Broca's area, where it is conveyed to the motor cortex to initiate articulation (Mayeux & Kandel, 1991).

Although Wernicke's model and subsequent models have contributed to our current understanding of brain lesions and language deficits, they do not necessarily explain the production of language in normal individuals. While the deficits can be correlated with damaged anatomical structures, the size and precise location of lesions is not exactly the same in all cases. Thus, corresponding generalizations to language production may be oversimplified. The model indicates that two areas of the cortex specialized for language, along with a few accessory areas, are involved in language production. Recent neurobiological research indicates that a new view of language may be hypothesized, one far more complex than the traditional Wernicke-Geschwind model involving Broca's and Wernicke's areas along with a few connecting structures (Geschwind, 1965; Damasio & Geschwind, 1984). A more plausible model would incorporate a larger number of brain systems into language, rather than simply one language-specialized system.

Recent technological developments have led to new methods of investigation that are non-invasive and do not require a language-deficient subject. One such method, Positron Emission Tomography (PET), is a brain imaging technique that allows researchers to make correlations between function and anatomy (Phelps, 1991a). PET determines the metabolic rate and the relative amount of blood flowing to a particular brain region, both of which are measures of the relative activity of that structure. This technique has allowed researchers to determine which parts of the brain are active during normal functions, such as attention, audition, or eye movement (Phelps, 1991a). Because of the increasingly high resolution of the imaging, the activity of a number of structures located throughout the brain may be simultaneously observed (Phelps, 1991b).

Use of PET, coupled with results from excision and electrical stimulation studies¹, has allowed researchers to identify whole neural systems involved in brain activities, such as language (production and comprehension). The resulting data indicate that numerous processes are involved in language production and acquisition and that each of these processes involves a variety of distinct yet interconnected structures. For example, for a second language learner to generate a sentence fluently requires the long term memory storage and retrieval of vocabulary, as well as internalized knowledge regarding the

application (and operationalization) of grammatical rules. A process known as long term potentiation, originating in the hippocampus and related structures, seems to lead to the memory needed for vocabulary storage. In addition, rapid retrieval and use of grammatical knowledge may be viewed as a procedural skill, thus involving the procedural knowledge memory system of the cerebellum in language (see Robbins, this volume).

Language is not a function that the cerebellum was expected to have and yet the data seems to indicate that it does have a role. Previous reports on the functions of the cerebellum focussed on the motor coordination role of that structure. Likewise, recent neurobiological data seem to implicate three areas previously unsuspected of playing a role in language. The fusiform gyrus appears on the underside of the brain and may not have been accessible to surgeons for lesion studies in times past. Known for its role as an association area, the anterior cingulate has previously been assigned the function of relaying sensory information to other areas of the cortex. The prefrontal cortex has long been associated with cognitive functions and planning, but never with language. Linking this region with language, indicates that not only this region, but any that play a role in the cognitive functioning of humans, may be involved in language. Because each of these regions is also known to play a role thought to be unrelated to language, they are excellent candidates for demonstrating the whole-brain perspective of language.

ANATOMY OF THE FUSIFORM GYRUS

The fusiform gyrus (also known as the lateral occipitotemporal gyrus) is a longitudinal fold of cortex located on the underside of the temporal lobe. Connections of this particular gyrus are not well established. A known link occurs between the fusiform gyrus and the area near the angular gyrus, an area adjacent to the traditional Wernicke's area (Bogousslavsky, Miklossy, Deruaz, Assal, & Regli, 1987). The basal temporal language (BTL) area, the focus of discussion here, is a small region located on this gyrus (see Figure 1).

Basal Temporal Language Area

Wernicke's area is generally accepted as the location where processing for language comprehension occurs. Electrical stimulation studies done by Luders and his colleagues have shown that the anterior portion of the fusiform gyrus also plays some role in language comprehension. They have named this small section the basal temporal language area (BTL).

Luders and colleagues originally located the area through a case study and then verified his findings in a more extensive study. In the case study, a man with intractable complex partial seizures was evaluated in preparation for surgical treatment of epilepsy (Luders, Lesser, Hahn, Dinner, Morris, Resor, & Harrison, 1986). The man tested normal for intelligence on the Wechsler Adult Intelligence Scale² and displayed no physical ailments other than epilepsy. A Wada test³ determined that he was left hemisphere dominant for the computational aspects of language.

Arrays of subdural electrodes were surgically implanted over the lateral and basal surfaces of the temporal lobe in the left hemisphere to identify the position of the epileptogenic focus in the left temporal lobe. Stimulation of the electrodes in the lateral temporal region over Wernicke's area produced speech interference, defined as an inability to read a text aloud. Writing was also inhibited. This same type of speech deficit was observed when the basal temporal region was stimulated. The patient was unable to comprehend either spoken and written language and could not repeat words spoken to him. Moreover, the patient could not write words he had been instructed to write prior to the start of stimulation. Essentially, a global aphasia was produced by stimulation of BTL. Luders and colleagues determined the aphasia to be a language specific interference by eliminating the other possible causes for speech arrest. The possibility of stimulation producing a seizure was eliminated, as no other clinical signs of a seizure were evident and none of the widespread electrical activity that usually accompanies a seizure was detected. The speech arrest was not due to a negative motor effect (motor inhibition due to stimulation), as the patient was still able to produce rapid alternating movements in his hands and lips. Nor did the stimulation produce a general processing interruption, as the patient was still able to memorize complex geometric designs and draw them from memory during stimulation. Luders

and colleagues concluded that they had happened upon a true language area.

Luders and his colleagues then performed a more extensive electrical stimulation study of 22 epileptic patients (Luders, Lesser, Hahn, Dinner, Morris, Wyllie & Godoy, 1991). In eight of the 22 patients, a basal temporal language area was identified, compared to 15 of 22 for Broca's area and 14 of 22 for Wernicke's area. In the eight patients who exhibited a basal temporal language area, the language deficit was elicited with stimulation only in the dominant hemisphere, never in the nondominant temporal lobe. Moreover, the degree of language interference, as measured by the ability to read aloud, was found to increase with the strength of the stimulation. Three of the 8 patients were tested in more detail to determine the extent of their aphasia. Two of the patients could not repeat words during stimulation; the third was able to communicate only by gestures. Verbal comprehension as tested by the Token test (following simple one and two-step commands) was inhibited by stimulation to some degree in all three. All three patients were also unable to name objects presented to them during stimulation. The patients all had severe agraphia (i.e., inability to write) during stimulation as well. As before, the language interference could best be characterized as a global aphasia in all the patients.

To verify the specificity of the language interference, several other functional tests were conducted. Using Koh's block tests (Stone, 1985) to examine intellectual function in two patients, Luders and colleagues found that they were able to perform relatively complex tasks without any sign of inhibitions. Motor activity was determined to be unaffected because rapid alternating tongue movement was possible (no negative motor effect). Patients also performed complex nonverbal tasks without difficulty and facial recognition posed no problems for the patients either. The occurrence of circumlocutions and the ability to communicate with gestures points to intact mental functioning, ruling out a disturbance of consciousness. These tests suggest that the language inhibition was not due to intellectual dysfunction, motor inhibition, or epileptiform disturbances of consciousness.

Luders and colleagues were able to identify the exact location of the basal temporal language area by controlling which electrode in the implanted array was used during the stimulation. X-rays and surgical inspection confirmed the positions of the electrode. The basal temporal area began about 3 to 3.5 cm from the anterior tip of the temporal lobe in all cases and varied at the

posterior end of the fusiform gyrus between 4 to 7 cm from the temporal pole (see Figure 2). The variation in size of the basal temporal area was not addressed by Luders and colleagues in reference to determining language loss.

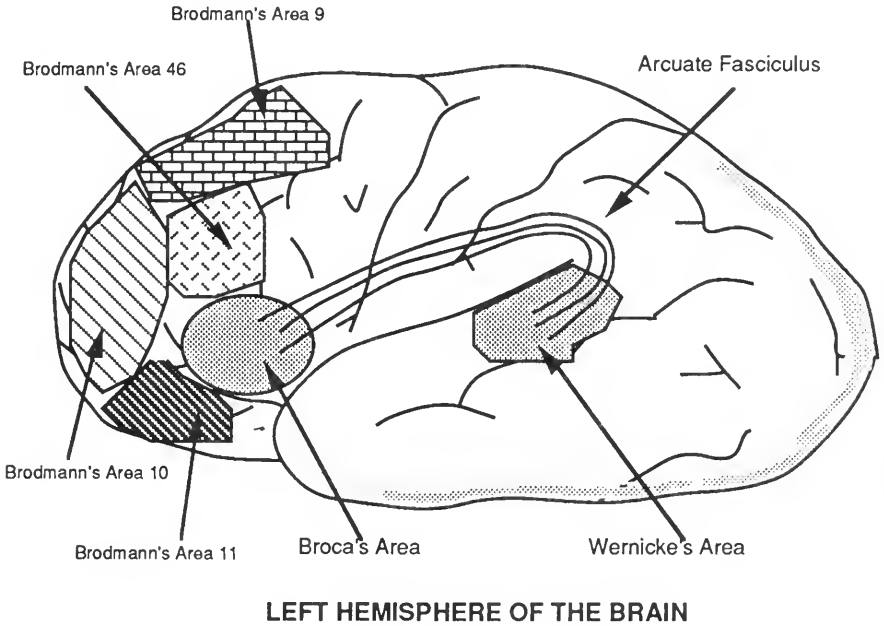


Figure 2. Diagram of the lateral (outer) side of the left side of the brain. The arcuate fasciculus is a bundle of fibers that extends from the temporal lobe, near Wernicke's area, curves around the angular gyrus and travels forward to the prefrontal cortex, near Broca's area. The prefrontal cortex is indicated as Brodmann's areas 9, 10, 11, and 46.

Three of the patients required removal of the basal temporal language area to treat their epilepsy and in two cases, no verbal deficit was detected postoperatively. In the third case, a slight temporary aphasia occurred that disappeared six months postoperatively.

THE FUSIFORM GYRUS (BTL AREA) IN LANGUAGE

The presence of a third language area is a surprising development that certainly requires modification of the Wernicke-Geschwind model for language processing, particularly because stimulation in the basal temporal area and Wernicke's area produced similar types of effects. A negative motor area (region of the brain which, when stimulated, causes inhibition of motor activity) overlaps parts of Broca's area and stimulation in non-motor regions within Broca's area produces similar effects. Noting that language inhibition was not produced in stimulation of any part of the inferior temporal gyrus, Luders and colleagues (1986) concluded that the basal temporal area is not merely a previously undetected portion of Wernicke's area, but a separate entity that may work in conjunction with the classical language areas. He also speculates that the expressive aphasia associated with Broca's area could be due to lesions in both the language and motor areas in that location while the communicative aphasia associated with Wernicke's area occurs because damage is confined only to language areas (Luders, Lesser, Dinner, Morris, Wyllie, & Godoy, 1988). In other words, if only the language areas within Broca's area were damaged, a comprehension aphasia would result and not an expressive one. Since similar deficits are produced in the three language areas, he inferred that they all work in conjunction and that an extensive direct connection must exist between these areas. The bundle of fibers called the arcuate fasciculus does indeed originate in the temporal lobe and travel back towards Wernicke's area (see Figure 2) before proceeding forward into the prefrontal cortex near Broca's area (Geschwind, 1979). Conduction aphasia, an aphasia involving fluent speech, poor speech repetition abilities and intact auditory comprehension seems to be an intermediate aphasia, having characteristics of both Broca's and Wernicke's aphasias. Anatomical evidence indicates that this third aphasia is caused by arcuate fasciculus lesions, disrupting the communication between Wernicke's and Broca's areas (Damasio & Damasio, 1980), as predicted by the Wernicke's original model (Geschwind, 1964; Damasio & Geschwind, 1984). A connection between the basal temporal region and Wernicke's area has not yet been identified, but Luders and colleagues hypothesize that it exists. They cite Rosene and Hoesen's (1977) work showing the existence of direct connections between the hippocampus and the cortex in the frontal and

temporal lobes as evidence for this possibility. Connections between the fusiform gyrus and the angular gyrus may also provide a possible indirect connection between Wernicke's area and this basal temporal language area.

If these three brain areas work in conjunction, the question arises why Broca's and Wernicke's area were able to be identified so much more frequently than the basal temporal language area. The surgical data suggests that the basal temporal region is not a crucial area since each of the three patients with a surgically removed basal temporal area demonstrated no postoperative aphasia, save one in which it disappeared after six months (Luders, et al., 1991). It is possible that the function is bilateral and that removal of the dominant hemisphere causes previously existing connections on the nondominant hemisphere to be reinforced, a process which requires time. It would be interesting to see whether a bilateral resection of the basal temporal region would reproduce the effects of electrical stimulation. Electrical stimulation tests on the basal temporal region of the nondominant hemisphere after recovery from resection of the basal region of the dominant temporal lobe may also provide that information.

The data suggest that a basal temporal language area definitely exists in some patients. Because it is not seen in every patient, the part it plays in the whole scheme of language generation remains partially unsure. Because the data indicates that there is no problem with the input (visual or auditory) stage, perhaps the interference lies in the processing stage, where the patients "had no access to the verbal engrams which establish the link between symbolic verbal material and the corresponding nonverbal expressions" (Luders et al., 1991, p. 751).

ATTENTION (DETECTION) AND LANGUAGE (The Anterior Cingulate)

One of the anterior cingulate's primary functions is in attention. In order to see the relevance of this structure to language, one must first understand the importance of attention to language processes. Thus, the role of attention in language will be addressed before a description of the anterior cingulate's anatomy is presented.

In addition to the processes mentioned above, adult second language learners also use conscious self-monitoring when

learning the second language, such as when the learner speaks, listens or writes (Chamot, Kupper, & Impink-Hernandez, 1988a, 1988b; Rubin, 1981). For example, in response to a verbal message, several steps must ensue. In a greatly simplified scenario, the auditory signal must first be filtered from all other stimuli (see Sato & Jacobs, this volume). The auditory signal is then processed in the brain to associate meaning with the sounds. Using the associated meaning, cognitive planning must then occur to determine the appropriate response to the auditory message. After the planning occurs, the appropriate brain areas are recruited to generate the response. Monitoring of the output is also necessary, particularly in nonfluent learners, to produce grammatically correct responses to the heard speech. This monitoring requires that attention be focussed on the appropriate stimuli, a focusing which has been shown to be a function of the anterior cingulate. The anterior cingulate may then be viewed as a participant in the self-evaluation process. The prefrontal cortex has been implicated in cognitive planning and organization and thus consequently also seems to play an important role in language. Although children seem to use these cognitive functions in first language acquisition, the prefrontal cortex is not completely developed during the time of the acquisition, thus complicating the picture. Neurons in the prefrontal cortex (specifically pyramidal cells in cortex layer III) continue to enlarge, both in cell body size and branching of the neuron projections, until approximately ten years of age (Mrzljak, Uylings, Van Eden & Judas, 1990). Neurons in the prefrontal cortex are also among the last neurons in the brain to myelinate (coat themselves with a fat-like substance) (Fuster, 1980). Because the extensiveness of neuron projections and myelination facilitate information exchange and, thus, processing, the prefrontal cortex cannot be considered fully functional until maturation is complete. Correspondingly, the functions of the prefrontal cortex are more easily defined in the adult second language learner (whose cortex has completed maturation). Thus our discussion will focus on the role of the prefrontal cortex and anterior cingulate in second language learning and production, rather than first language acquisition.

The acquisition and production of a second language in adults involve a general attention system. For the purpose of this paper, attention is defined as "the ability to select or focus on a small fraction of the incoming sensory information" (Corbetta, Miezin, Dobmeyer, Shulman & Petersen, 1991). Within this

definition, attention may be parsed into three functions (Posner & Petersen, 1990): 1) orientation to sensory information, 2) detection of specified information for processing, and 3) maintenance of alertness. Only detection will be dealt with here since it is involved in language and self-evaluation.

Detection is defined as the identification of a targeted item (Posner & Petersen, 1990). That target includes information in stored memory as well as sensory data. In the process of language production and acquisition, detection provides the means by which a learner can monitor his language production. For example, using Bialystok's (1978) model of second language learning, consider a nonfluent adult learning Spanish as a second language. When speaking, the learner will consciously identify the subject of the sentence and then mentally review a list of verb forms to find the appropriate one, before, during, and after generating the sentence. Krashen's (1981) monitor model posits the use of conscious self-evaluation when actively studying to learn a language, but not during "acquisition," the unconscious learning of a language. Detection may then be viewed as monitoring in Krashen's monitor model. This detection also allows the learner to evaluate the responses of the listener.

The generalized attention system, under which detection falls, may be viewed as two smaller entities, the posterior and anterior attention systems (Posner & Petersen, 1990). It is the anterior system that plays a key role in detection during cognitive functions, which include language. Within the anterior attention system, one of the main players is the anterior cingulate, thus, it will be the focus of the discussion on attention (detection) and language.

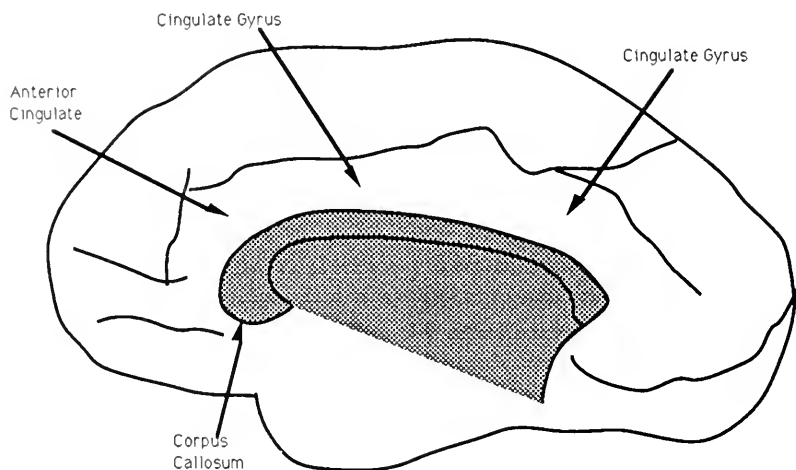
ANATOMY OF THE ANTERIOR CINGULATE GYRUS

The anterior cingulate gyrus is an outward fold in the cortex, located on the medial surfaces of the frontal lobes in both hemispheres of the brain. The cingulate gyrus curves around the corpus callosum, the bundle of fibers connecting the two hemispheres (See Figure 3).

The distinction between the anterior and posterior regions of the cingulate is important since the two regions have differing input connections (Vogt, 1985) and functions (Vogt, 1987). The

posterior cingulate is involved in pain and reactions to noxious stimuli. The anterior cingulate is the portion of the gyrus to which the language functions are being ascribed.

The anteriomedial and mediothalamic nuclei provide the majority of thalamic input for the anterior cingulate (Vogt, 1985). The anterior cingulate also receives input from higher order sensory cortex (not primary sensory cortex) and sends output to the prefrontal cortex (Kupfermann, 1991). Existence of connections between the prefrontal cortex and the anterior



MEDIAL VIEW OF THE BRAIN

Figure 3. Medial View of the right side of the brain. The anterior cingulate is the fold of brain tissue just above the corpus callosum. The anterior portion of the cingulate is pointed out above.

cingulate would increase the possibility that they affect each other during language processing, if that is shown to be a function in either location. As the main input to the anterior cingulate, the mammillothalamic tract will also prove to be important. Consequently, the mammillothalamic tract and the connection with the prefrontal cortex are central to the discussion presented below.

THE ROLE OF THE ANTERIOR CINGULATE IN DETECTION/SELECTION

Regional blood flow in the brain has been shown to increase in the anterior cingulate during single word association tasks (Petersen, Fox, Posner, Mintun & Raichle, 1988). These tasks required normal subjects to generate a verb semantically related to a visually presented noun (e.g., "eat" when presented with "food"). Subjects were also asked to monitor lists of words, identifying those belonging to a particular semantic category (e.g., searching a word list for different foods). PET data indicated activation of the anterior cingulate in both tasks. Interestingly, the amount of activation seen in the anterior cingulate was found to be greater for lists containing many words from the selected categories (Petersen et al., 1988; Petersen, Fox, Posner, Mintun & Raichle, 1989). Activation in a part of the left prefrontal lobe was also observed. However, similar blood flow increases were not seen during visual presentation alone (no response required from the subject), nor during an output task in which the subject verbally repeated the word presented on the screen.

The verb generation task included speech (reporting the verb), visual processing, and semantic association between a verb and a noun and possibly some type of grammatical computation in identifying the part of speech. The amount of activation in each task was determined by subtracting the numerical values of activation determined by PET from the PET results of nearly identical tasks, differing only in one aspect of the task. For example, PET values of a person viewing and reading a printed noun were subtracted from a PET of one viewing a noun and speaking an associated verb. The semantic association is the only difference between the two tasks (Petersen et al., 1989). The results showed that the anterior cingulate and lateral prefrontal cortex were active and suggests that they were involved in that association. The anterior cingulate was also implicated in the detection and selection of words because its activation only increased on the word lists tasks with more target words (Posner, Petersen, Fox & Raichle, 1988; Petersen et al., 1988; Petersen et al., 1989). In contrast, the lateral prefrontal cortex activation did not vary with the number of targets in the lists.

The fact that activation of the anterior cingulate is stronger in searching lists with more targets strongly suggests that the cingulate is involved in detection. The only difference between the tasks of searching a list with fewer targets and searching a list

with more targets is the detecting of the targets and generating responses, the latter also being considered a function of the anterior cingulate in detection or "attention for action" (Posner et al., 1988), meaning that the anterior cingulate selects a processing center or a course of response for the stimuli.

Pardo, Pardo, Janer, and Raichle (1990) have also studied the anterior cingulate in a verbal task. Their task was constructed under the Stroop attentional conflict paradigm in which subjects had to resolve the interference between word reading and color naming (Pardo et al., 1990). For example, subjects were presented the word "red" in green letters and asked to name the color of the letters as quickly as possible. Although the Stroop task is different from the Petersen, Fox, Posner, Mintun, and Raichle (1988) experiments, both tasks require a shunning of the tendency to read the noun presented while generating another word. Although it does not require a selection/detection of external data, the Stroop task demands selection of the relevant processing center to which the information is sent (Pardo et al., 1990). PET data from these Stroop conflict tests show the greatest activation to be in the anterior cingulate. This lends support to the idea that the anterior cingulate participates in the selection of a processing center or cognitive operations.

PET scans performed by Corbetta, Miezin, Dobmeyer, Shulman, and Petersen (1991) have indicated that the anterior cingulate is active not only in language specific tasks, but also during tasks requiring complex cognitive functioning. Their experiments examined two situations: a selective attention and a divided attention task. In the selective attention task, subjects were required to detect the changes in a single, specific feature (size, color, shape or speed) of moving blocks in visual screen. Other features were either constant or also shifting during the tests. Alterations in features not specified by the researchers were to be ignored during the selective attention task. In contrast, the divided attention task required detection of a change in any feature; no feature was specified for the subject to focus on.

A number of brain regions were activated in both tasks; but only in the divided attention task was the anterior cingulate activated. The prefrontal cortex was also activated in the divided task. The data indicate that, cognitively, the brain views the two tasks "as qualitatively different" (Corbetta et al., 1991, p. 2398). The selective attention task necessitated the maintenance of a focus on a specified feature. However, the divided attention task did not involve a preset focus, but rather imposed greater demands

in the coordination and comparison of information. Corbetta, Miezin, Dobmeyer, Shulman, and Petersen (1991) surmise that all the sensory information regarding the various features is processed in the prefrontal cortex, which then sends data to the anterior cingulate for response selection.

That the anterior cingulate functions preferentially in cognitive tasks was demonstrated in an experiment by Pardo, Fox and Raichle (1991). The tasks involved were solely sustained attention tasks for somatosensory stimuli (e.g., noticing touches on a toe or changes in the intensity of a light). The authors concluded that the task did not require use of "high-level processing selection systems necessary for the analysis of complex targets" (p. 63), and thus did not require the anterior cingulate's usage.

Raichle (1990) has noted that activation in the prefrontal cortex and the anterior cingulate during Petersen, Fox, Posner, Mintun, and Raichle's (1989) verb generation task was only found when the task was first presented to the subjects. As a "new" task, it required active attention. However, after the task had been rehearsed (e.g., practicing the generation of verbs for one specified list of nouns and being tested for the same list), activation of the prefrontal cortex and anterior cingulate was no longer seen. In other words, after the task had been automated by continuous practice, the attention was no longer needed. Language acquisition is similar; once the grammatical structures are "acquired", they become automatic. The anterior cingulate may have a role in language acquisition through detecting features or selecting responses when the situations are still novel. Processing for the responses occurs elsewhere when the responses have been practiced enough for the cerebellum to ingrain them into procedural memory.

ANATOMY OF THE PREFRONTAL CORTEX

The prefrontal cortex is located in the anterior lateral portions of the cerebral cortex, corresponding to Brodmann's (1909) areas 9, 10, 11 and 46 (see figure 1). The connectivity of the prefrontal cortex extends throughout the brain. This high degree of connectivity would allow it to play the role of integrator of sensory information in the divided attention task mentioned above (Corbetta et al., 1991). For the present purposes, the most

important connections are with the thalamus and the anterior cingulate.

COGNITIVE FUNCTIONS OF THE PREFRONTAL CORTEX

Lesion studies of patients have indicated that the prefrontal cortex is involved in cognitive planning. Lesions in the prefrontal area lead to a disorder termed "central motor aphasia" (Goldstein, 1948), which is characterized by slowed spontaneous speech and a low level of expressivity. Jackson (1915) reports that the patients speak in short, simple sentences, almost as if their ability to use complex sentences (e.g., those with subordinate clauses) is reduced. Fuster (1985) concludes that these lesions impair the ability to organize complex language and to sequence the shorter clauses for the longer sentences. Stuss and Benson (1984) report four main behavioral deficits as a result of prefrontal damage: a) an inability to use knowledge about a task to complete a task, b) inability to monitor behavior for errors and to use the errors to modify behavior, c) inability to establish a set (frame of reference), and d) impaired ability to perform sequential tasks. Citing the connections between the frontal and prefrontal cortex, McGrath (1991) speculates that breakdowns in the looping connections between the two areas cause the observed impairment, much of which affects the quality of language produced.

Novoa and Ardila (1987) report that patients with prefrontal lesions retain the formal aspects of language such as lexical and phonetic knowledge. However, patients were slow with verbal tasks and showed signs of perseveration, free association of ideas, and noticeable failures in verbal memory. Consequently, Novoa and Ardila suggest that the lesions cause loss or impairment of the capacity to elaborate, or express decisions about language.

A recent study by Kelly, Best and Kirk (1989) on the reading abilities of boys also implicates the prefrontal cortex in problem solving and selective attention. They examined a number of cognitive functions considered to be exclusively the domain of the prefrontal cortex and some functions considered to be the domain of the posterior cortical areas. The subjects of their study were boys who either were able to read (control group) or had

been identified as having difficulty learning to read. They found that those with a hindered ability to read or to learn to read showed a deficit in prefrontal functions. These boys did not consistently use new information to reformulate hypotheses in a problem solving task, nor were they able to maintain attention to certain aspects required by the tasks, such as color of the letters in the Stroop test (see above). They conclude that the "reading disabled youngsters have difficulty with cognitive processes involving sustained attention, inhibition, set maintenance [keeping a frame of reference], and flexibility in generating alternative hypotheses" (p. 289).

Although the above research indicates that the prefrontal cortex is involved in planning and using feedback in planning responses, recent PET evidence indicates some language-specific functions may be attributed to the prefrontal cortex as well. In the divided attention, but not the selective attention, task mentioned above (Corbetta et al., 1991), the prefrontal area was identified as an active area along with the anterior cingulate. Corbetta, Miezin, Dobmeyer, Shulman, and Petersen, (1991) attribute processing for complex-tasks to this area because it is very close to the areas found to be active in the semantic association tasks of Petersen, Fox, Posner, Mintun, and Raichle. (1988).

Petersen, Fox, Snyder, and Raichle (1990) have also presented evidence that the prefrontal cortex participates in language functions. Their PET scan study indicates that the prefrontal cortex is active when real words are presented visually, while meaningless symbols or nonword-like strings (e.g., *sweed*) do not cause similar activations. Petersen, Fox, Snyder, and Raichle (1990) argue that this area is involved in semantic association since the word form is similar in word-like strings of letters and true words, the only difference being the association of a meaning with the word and none with the word-like form.

The available data on the prefrontal cortex indicates that it is involved in planning cognitive tasks and in evaluating behavior. PET studies indicate a semantic association function as well. In relation to adult second language acquisition then, the prefrontal cortex may participate in planning and editing language from sentence level grammar up to cohesion in discourse (McGrath, 1991). This planning and editing function can provide a plan for evaluation which both it and the anterior cingulate may perform. Such an evaluation could then serve as the criteria that the anterior cingulate uses to determine the next area in the brain where further processing will occur (e.g., the motor areas for producing a

spoken reply to a call). The prefrontal planning role would only be in effect during the acquisition of the second language in adults since automating some of these grammar and discourse plans due to constant practice would relate responsibility of their performance to the cerebellum, to which both the prefrontal cortex and the anterior cingulate are connected (Leiner, Leiner & Dow, 1989).

SYNTHESIS

The fact that language-related functions can be localized in these three previously unrelated structures indicates that a whole-brain view of language may be in order. If the BTL area, the prefrontal cortex, and the anterior cingulate have long remained unassociated with language functions, the probability that other areas of the brain which contribute to language could also go unacknowledged by neurolinguists is very high. While the Wernicke-Geschwind model has proved useful in language/brain research, current neurobiological knowledge has shown it to be oversimplified. Because the Wernicke-Geschwind model presupposes a language-specific system in the brain, it automatically narrows the focus to brain regions near or directly related to Wernicke's or Broca's area. It thus directs research away from areas in which lesion-caused language deficiencies have not been noted yet, areas which may later prove to be crucial to language research.

Although the existence of areas outside the Wernicke model clouds the picture for explaining language, it points to a wide range of opportunities for further research in the brain/language field. The possibilities of identifying brain regions active in language and yet traditionally associated with other functions, such as the amygdala which functions in emotion (Schumann, 1990), hold out the chance that identification could lead to a greater understanding of the nature of second language learning and production, and even language itself.

NOTES

¹ In electrical stimulation studies, electrodes are implanted in the brain over the area to be studied. Application of an electrical current there disrupts the normal electrical activity of the neurons and thus inhibits their functioning. Behavioral correlations to these structures can be made during stimulations, which, in effect, produce a "temporary" brain lesion.

² The Wechsler Adult Intelligence test measures cognitive functioning.

³ The Wada test involves injecting sodium amytal into the blood supply of either the right or the left hemisphere of the brain. Since it is a barbiturate and will slow down normal brain functions, sodium amytal determines which side of the brain is language dominant by identifying the hemisphere in which language functions are hindered upon injection.

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Lawrence Lem is a graduate student in the Department of TESL & Applied Linguistics at UCLA.

A Neurobiological Model of Procedural Linguistic Skill Acquisition

Scarlett L. Robbins
University of California, Los Angeles

This paper presents a neurobiologically inspired model of one aspect of adult second language acquisition (SLA): procedural linguistic skill acquisition. Procedural linguistic skills are defined as the speaker/learner's implicit, unstatable knowledge regarding the formal linguistic (i.e., syntactic, phonological, and morphological) properties of the second language (L2). Unlike declarative linguistic knowledge (i.e., semantic and lexical knowledge and explicit knowledge of the L2 linguistic system), which can be readily displayed through verbal report or description, procedural linguistic skills are best demonstrated through performance. The proposed acquisition model crucially involves the neural circuitry of the neocerebellum. The neocerebellum is a brain structure which, although traditionally associated with purely motor activity, has recently been implicated in higher cognitive and, potentially, linguistic functions. The model provides for a potential unification of the competing cerebral (Ojemann, 1991; Loritz, 1991) and cerebellar (Rumelhart & McClelland, 1986; Sokolik, 1990) theories of linguistic function by integrating the unique contributions of both regions of the cerebral cortex (e.g., Broca's expressive speech area and the prefrontal cortex responsible for cognitive planning and monitoring functions) and regions of the cerebellum (an enormous capacity parallel processor responsible for the integration of cognitive and sensory information). The proposed model also offers a principled account of how explicit formalized grammar instruction might potentially serve as an effective metacognitive strategy for the L2 learner's acquisition of procedural linguistic skills.

INTRODUCTION

This paper presents a neurobiological model of one aspect of adult second language acquisition (SLA): procedural linguistic skill acquisition.¹ Procedural linguistic skills are defined for present purposes as the speaker/learner's implicit, unstatable knowledge of the structure and form of the second language (L2), including knowledge of the so-called "abstract rules" of the syntax, phonology, and morphology of the L2. Procedural linguistic skills concern those aspects of the L2 linguistic system which speaker/learners "know" only in the sense that they are able to produce grammatical strings in the L2 which both reflect and obey these underlying rules, principles and constraints; "naive" speaker/learners are largely unable to describe this knowledge in significant detail or with much accuracy. I refer to this type of "knowledge" as a skill precisely because it is best demonstrated through performance, rather than through verbal or written report. Not all knowledge about language, however, is implicit and unstatable; speaker/learners also have a significant amount of explicit knowledge about the L2. This explicit and statable knowledge is referred to as declarative linguistic knowledge; examples include lexical and semantic knowledge, and explicit formally learned knowledge of the syntactic, phonological, and morphological properties of the L2. As an illustrative example consider the phonological and morphological knowledge that speaker/learners of English have about the noun "house." They possess explicit declarative knowledge that the plural form of the noun is "houses" (/hauzIz/), but they also have implicit procedural linguistic knowledge of the Obligatory Contour Principle (a constraint which essentially forbids adjacent identical elements or features within a phonological constituent) which, in this case, forces the epenthesis (insertion) of the default vowel /I/ to separate the two adjacent identical consonants.²

Essentially, the proposed model assumes that the acquisition of procedural linguistic skills in an L2 involves the gradual, stage-wise formulation and refinement of detailed execution programs within the neural circuitry of the neocerebellum and related structures. Adult procedural linguistic skill acquisition is represented within this model as the operationalization of "abstract" or conceptual linguistic plans originating in Broca's expressive speech region under the monitoring and strategic planning influence of the frontal cortex. Through its integration of diverse brain

structures including regions of both the cerebral hemispheres and the cerebellum the model presented here offers a potential unification of the currently competing cerebral (Ojemann, 1991; Loritz, 1991) and cerebellar (Rumelhart & McClelland, 1986; Sokolik, 1990) models of linguistic function.

I would like to begin this paper by making explicit a number of assumptions and theoretical preferences which underlie the proposed model of adult L2 procedural linguistic skill acquisition. Then, I will briefly describe the neurobiological processes involved in the acquisition and storage of knowledge (i.e., learning and memory) and offer a general sketch of a larger inclusive neurobiological model of SLA into which the present model of procedural linguistic skill acquisition might fit. Finally, I will present the model and discuss the potential contributions of this avenue of research to the overall understanding of the processes involved in adult SLA.

Underlying Assumptions of Proposed Model

First, the proposed model is neurobiologically inspired; it relies crucially on Squire's neurobiological theory of memory (Squire, 1982, 1985, 1986, 1987; Squire & Zola-Morgan, 1991) and is based upon neurobiological models of voluntary motor activity (Ghez, 1991) and procedural motor skill learning (McCormick & Thompson, 1984; Thompson, 1986, 1989; Harrington, Haaland, Yeo & Marder, 1990; Bloedel, Bracha, Kelly & Wu, 1991; Greenough & Anderson, 1991). As Jacobs & Schumann (1992) argue, it is important that any model or theory which purports to account for language acquisition (either primary or second) be at least neurobiologically plausible. If we are ever ultimately to understand how human language is acquired, we must begin to consider how the human brain, given what we know of its anatomical structure and its physiological function, might acquire language.

Secondly, much of the neuroscientific research upon which the present model is based is concerned with non-linguistic learning and memory (i.e. the acquisition and storage of knowledge) in both non-human and human subjects. I maintain, however, that it is valid to build a model of linguistic skill acquisition upon this research for the following reasons. First, a number researchers have argued that adult SLA is in many ways similar to the acquisition of other complex cognitive skills and is, to a significant extent, dependent upon "general" cognitive learning processes

which are not specific to language (Bialystok & Ryan, 1985; Faerch & Kasper, 1985; McLaughlin, 1987; O'Malley & Chamot, 1990). Second, although much current neuroscientific research is performed on non-human subjects, the findings are to a surprising degree generalizable to human subjects and the data available from cross-species comparisons support the notion that the "*fundamental neurobiological structure and principles* remain the same across mammalian species" (Jacobs & Schumann, 1992: 285, emphasis theirs). I want to emphasize, however, that although I agree with Klein's assertion that "the capacity to acquire and use a language is a species-specific genetic endowment" (Klein, 1990: 219), the present model makes no assumptions regarding the issue of the innateness of linguistic ability in humans and is entirely consistent with both the environmentalist (cf. Jacobs, 1988; Greenfield, 1991) and the nativist-constructivist (cf. Crain, 1991; Karmiloff-Smith & Johnson, 1991) views of language acquisition.

Third, the present model of procedural linguistic skill acquisition presupposes a larger model/theory of SLA in which the acquisition of competence in an L2 is assumed to involve the acquisition of at least the following four distinct components: a motor skill component responsible for phonetic speech output; a general cognitive component concerned with cognitive skills related to the use of language which are not specifically linguistic, such as reasoning, development of plans for behavior, and the strategic use of available resources and capacities to achieve a goal; a declarative linguistic skill component which consists of the speaker/learner's explicit knowledge of the linguistic system; and a procedural linguistic skill component which comprises the speaker/learner's implicit knowledge of the structure and form of the language.

Fourth, although this model presumes the existence of a localized and distinct neural system devoted to language function, the proposed system is less modular and restrictive than traditional neurolinguistic models such as those presented by Geschwind (1970) and Ojemann (1987) which concern themselves primarily with strictly defined regions of the left cerebral hemisphere (i.e. Broca's and Wernicke's areas). The present model postulates a neural system which is self-contained yet distributed within a circular loop across several distinct brain regions including both the cerebral and the cerebellar hemispheres (for discussion of the role of additional brain structures in language function see Lem, this volume and Sato & Jacobs, this volume). The present model is not only a more plausible representation of the functional organization of the brain than the strictly modular traditional neurolinguistic models³

but also offers a possible compromise between two currently competing theories of linguistic representation: the symbolist, or cerebral theories proposed by researchers such as Loritz (1991) and Ojemann (1987) and the connectionist, or cerebellar theories such as those of Rumelhart and McClelland (1986) and Sokolik (1990).⁴

Neurobiology of Learning and Memory

Memory is assumed to consist of information, or knowledge, which is stored and retrieved through the patterns of synapses (i.e., communicative connections between neurons) existing within a given neuronal network (Squire, 1987; Kupfermann, 1991; Thompson, 1987). Knowledge is stored, or acquired, through local changes occurring within a particular neural network. Local changes, which constitute the neural mechanism for learning, may involve either morphological or chemical alterations. Morphological alterations include the formation of new synapses and the structural modification of preexisting synapses. Chemical changes involve the alteration of the membrane properties of neurons, which in turn may influence the functional properties of potential or preexisting synapses.

Given that learning involves the formation of new synapses and/or the morphological or chemical modification of synapses, the acquisition of novel information crucially depends upon the existence of "plasticity" within the relevant neuronal circuitry. Plasticity is defined as the capacity of a given neuronal network to create new synaptic connections or modify preexisting ones in response to novel input from the environment, either external or internal (i.e., the capacity to learn). Plasticity has been documented within numerous neural systems including those relevant to the present discussion: the cerebral cortex and the cerebellum (Purves & Litchman, 1980); the hippocampus and related cortical areas (Squire & Zola-Morgan, 1991); and the red nucleus, a brain stem structure receiving massive projections from the neocortex (the most recently evolved portion of the cerebral cortex) (Tsukahara, 1984). The importance of plasticity within each of these functional neural systems will be discussed in greater detail in later sections.

OUTLINE OF LARGER INCLUSIVE MODEL OF ADULT SLA

Motor Speech Component

One aspect of SLA involves the acquisition and fine-tuning of the purely motor skills required for fluent and accurate phonetic speech production. The realization of the L2 linguistic system as phonetic speech output requires the formulation and automaticization of highly detailed motor programs that encode the precisely timed and coordinated neuronal impulses which ultimately result in a complex set of muscle movements. Although the motor neurons which directly innervate the muscles of the speech organs are located in Brodmann's areas 4 & 6 of the cerebral cortex⁵, research suggests that the cerebellum plays an integral role in the acquisition and orchestration of motor speech activity (Figure 1).

Although research in this area remains speculative, it is generally accepted that the basal ganglia, the cerebellum, and related neural circuitry are responsible for the acquisition and storage of certain types of procedural motor skills (Harrington, Haaland, Yeo & Marder, 1990; Bloedel, Bracha, Kelly & Wu, 1991; Ghez, 1991). The structures of the basal ganglia are reportedly involved in the facilitation and inhibition of movement, as well as the regulation of movement speed (Ghez, 1991); the cerebellum is reportedly responsible for the acquisition and storage of the detailed motor activity programs which underlie a restricted subset of procedural motor skills: those which crucially require the neural circuitry of the cerebellum for their execution (McCormick & Thompson, 1984; Thompson, 1986, 1989; Bloedel, Bracha, Kelly & Wu, 1991; Greenough & Anderson, 1991). Research suggests that the cerebellum is indeed crucially involved in phonetic speech production (Ivry & Keele, 1989; Raichle, 1990) and may therefore be responsible for the acquisition and storage of the procedural motor speech programs which are responsible for modulating and orchestrating motor speech activities. In fact, it has been suggested that the evolutionary development of phonetic speech ability (an ability which depends upon high-speed processing and the integration of mental and motor activity) in humans was largely the result of the phylogenetic enlargement of regions of the neocerebellum (Leiner, Leiner & Dow, 1987: 429).

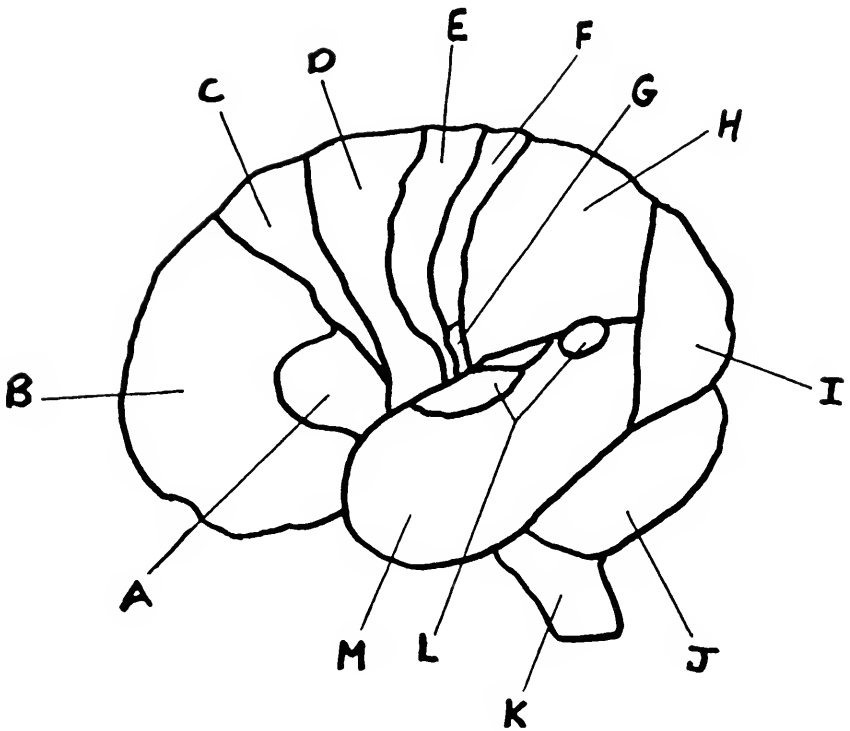


Figure 1. Sketch of lateral view of human brain identifying numerous functional and anatomical regions. A=Broca's Area 44 & 45, B=Frontal Lobe, C=Area 8, Prefrontal Cortex, D=Area 6, Supplementary Motor Cortex, E=Area 4, Primary Motor Cortex, F=Primary Sensory Cortex, G=Secondary Sensory Cortex, H=Parietal Lobe, I=Occipital Lobe, J=Cerebellum, K=Brain Stem, L=Wernicke's Area 22 & 42, M=Temporal Lobe.

General (Non-Linguistic) Cognitive Component

Certain aspects of the acquisition and production of a second language are assumed to be extra-linguistic, involving general cognitive capacities such as reasoning, the development of plans for future actions, and the strategic direction and integration of available resources towards a specified goal. The prefrontal region of the cerebral cortex (cf. Figure 1) is generally acknowledged to be responsible for the cognitive functions of abstract reasoning, weighing the consequences of future actions, and planning

accordingly (Fuster, 1988, 1992; Kupferman, 1991). It is likely that the prefrontal cortex is also responsible for the acquisition of these same skills as they relate to the use of a second language. Research supports the notion that the prefrontal cortex is responsible for the reasoning and planning activities required for the utilization of language to conceptualize, elaborate, and express our thoughts (Novoa & Ardila, 1987). After reviewing the substantial clinical and experimental research, Stuss and Benson (1984) conclude that frontal lobe lesion studies support a role for the frontal lobe in organization and sequential planning, monitoring of behavior, directed attention, and error detection. Numerous studies document the following impairments in patients following frontal lesions: (1) an inability to use verbalized (i.e., declarative) knowledge to guide motor activity, (2) an impaired ability to organize sequential behaviors, (3) an impaired capacity to direct and maintain attention, and (4) an impaired ability to monitor on-going activity (Stuss & Benson, 1984: 22-23). Patients with prefrontal damage are typically observed to display generally intact formal linguistic systems and yet are significantly impaired in their ability to use their linguistic resources strategically to accomplish desired linguistic behaviors or achieve communicative goals (Novoa & Ardila, 1987). These findings have led researchers to conclude that the linguistic impairments observed in patients with prefrontal damage are not due to deficits in specifically linguistic functions, but are instead the result of their generally impaired ability to exercise control over behavior, focus voluntary attention appropriately, and develop plans which direct their activities towards a specified goal (Novoa & Ardila, 1987: 207).

Specifically Linguistic Components

The current model fundamentally assumes a distinction between two types of linguistic knowledge and proposes two separate components devoted to specifically linguistic knowledge: one involving declarative linguistic knowledge and the other procedural linguistic skills. This proposed distinction between declarative and procedural knowledge originated within the fields of artificial intelligence (Winograd, 1975) and cognitive psychology (Anderson, 1976) and was recently applied to specifically linguistic knowledge by a number of researchers interested in SLA (Anderson, 1980, 1985; Bialystok & Ryan, 1985; Faerch & Kasper, 1985; O'Malley & Chamot, 1990). For instance, Faerch and Kasper (1985) classified semantic knowledge of word meaning

and explicitly "learned" rules of grammar as declarative, and strategies and procedures used to implement declarative knowledge as procedural knowledge; O'Malley and Chamot (1990) described declarative linguistic knowledge as knowledge "about" how to use language and procedural knowledge as the skills required to actually use language as a communicative tool. Unfortunately, despite obvious implications for research and theory, SLA researchers have generally been hesitant to pursue this distinction, perhaps because of the imprecise and confounding way in which the terms "declarative" and "procedural" are often used. Among those who have addressed the topic there has been significant debate concerning the extent to which these two types of knowledge differ in the nature of their representation in memory, the degree to which one type of knowledge can be transformed into the other type, and even the feasibility of accurately classifying knowledge as being either declarative or procedural (Anderson, 1980, 1985; Bialystok & Ryan, 1985; Faerch & Kasper, 1985; O'Malley & Chamot, 1990). It is interesting to note that the question of whether and how declarative knowledge might be transformed into procedural knowledge is reminiscent of the longstanding debate in SLA research concerning the possible facilitatory role of "learned" linguistic knowledge in the subsequent "acquisition" of that knowledge (Lamendella, 1979; Krashen, 1981; Gregg, 1984; McLaughlin, 1987).

The declarative/procedural distinction has also been adopted by neurobiological researchers and incorporated within their theories of learning and memory (Cohen & Squire, 1980, 1981; Squire, 1982, 1985, 1986, 1987; Tulving, 1987; Kupfermann, 1991; Squire & Zola-Morgan, 1991). Researchers working within this neurobiological paradigm have been able to formulate more precise and theoretically constrained definitions of each type of knowledge, offer substantial clinical and experimental evidence supporting the validity of the proposed declarative/procedural distinction, and clarify the possible facilitative role of declarative linguistic knowledge in the acquisition of procedural linguistic knowledge. Squire and Zola-Morgan (1991), for example, have developed a taxonomy of knowledge types which distinguishes between declarative (factual and episodic) knowledge and non-declarative knowledge. Non-declarative knowledge comprises several distinct sub-types of knowledge including: procedural skill knowledge, priming, simple classical conditioning, and non-associative knowledge. Only two of these sub-types of knowledge are relevant

to the present discussion: declarative knowledge, and procedural skill knowledge.

For present purposes I will assume that declarative linguistic knowledge refers to the speaker/learner's lexical and semantic knowledge and explicit, formally "learned" knowledge of the rules of the L2 grammar (e.g., memorized and storable knowledge of grammatical rules), while procedural linguistic skills consist of the speaker/learner's implicit knowledge of the "abstract rules" related to the sequencing, coordination, and combination of linguistically relevant units (phonemes, morphemes, words, phrases, etc.) into grammatical configurations as required for the actual use of the L2 in real-time as a communicative tool. Thus, a defining characteristic which can help to identify knowledge as being either declarative or procedural in nature is the means by which it can be demonstrated: declarative knowledge can be explicitly verbalized and procedural skills can be performed. However, this distinction does not preclude the possibility of learners acquiring declarative knowledge related to the performance of an essentially procedural skill, perhaps even without adequately acquiring the procedural aspects required for the performance of the skill. This may, in fact, be precisely what is happening to learners who are able to demonstrate accurate grammatical knowledge of the L2 "declaratively," yet are unable to *use* this knowledge "procedurally."

As an additional example of each type of linguistic knowledge consider what speaker/learners of English know about the word "give." Declarative linguistic knowledge of "give" includes the fact that "give" symbolically encodes the following concept: the transfer of possession or ownership of some object or entity from one party to another, as a result of some action of the first party. Procedural linguistic skills related to "give" include the speaker/learner's implicit, encoded knowledge that "give" must appear in syntactic constructions as the head of a verb phrase containing two arguments (a direct and an indirect object), assigns inherent case, and thereby licenses dative alternation of its direct and indirect objects.⁶ It is worth emphasizing that speaker/learners may possess significant amounts of procedural knowledge related to the syntactic, phonological, and morphological properties of a word and yet be largely or entirely unable to express this knowledge verbally, as in the case of untutored, naturalistic L2 learners who have little if any declarative knowledge of the L2 system beyond their semantic and lexical knowledge.

The validity of the distinction between declarative and procedural knowledge types rests primarily on the extensive clinical

and experimental research performed with human amnestics and lesion studies performed upon laboratory animals. Patients with lesions localized to the medial temporal lobe of the cerebral cortex, resulting either from surgery or injury, have been reported to demonstrate a significant loss of prior declarative memory (retrograde amnesia) in addition to a severely impaired capacity to acquire declarative knowledge (anterograde amnesia) (Milner, 1966; Warrington & Weiskrantz, 1982; Squire, 1986; Squire & Zola-Morgan, 1991). Although the extent to which prior memories are lost varies considerably, most patients retain a significant portion of their remote memory (i.e., memory stored many years prior to damage). The capacity of these patients to acquire and retrieve procedural knowledge, however, remains remarkably intact (Warrington & Weiskrantz, 1982; Squire, 1986; Tulving, 1987). Despite an inability to remember even the simplest facts, amnestics demonstrate a normal ability to acquire novel, complex procedural skills such as reverse mirror reading (Cohen & Squire, 1980). Thus, the defining characteristics of human amnesia, a significant impairment of declarative memory in conjunction with spared procedural memory, support the existence of separate memory/knowledge systems that are dependent upon distinct neuroanatomical structures for their acquisition and storage (Squire, 1986; Tulving, 1987; Kupfermann, 1991; Squire & Zola-Morgan, 1991).

In the sections below, I will briefly present what are currently considered the most plausible neuroanatomical substrates for each type of linguistic knowledge. However, I would like to point out that the fundamentally distinct character of these two types of knowledge, declarative being a chunk of information and procedural a detailed program for activity, as well as their dependence upon distinct neuroanatomical systems, make it entirely inconceivable that knowledge of one type could ever be "transformed" into knowledge of the other type. However, this does not preclude the possibility that previously acquired knowledge of one type may facilitate the subsequent acquisition of related knowledge of the other type, which is essentially what I will propose in a later section of this paper.

Anatomical substrate for declarative linguistic knowledge/memory

Recent research on human amnestics and non-human primates provides compelling evidence that the medial temporal lobe

system (consisting of the hippocampus, the parahippocampal gyrus, and the entorhinal and perirhinal cortices) is primarily responsible for and crucially involved in the acquisition and storage of declarative knowledge, although the actual site of long-term memory storage most likely lies outside of this region (Squire & Zola-Morgan, 1991; Plummer, 1991).

The acquisition of declarative knowledge (including specifically linguistic declarative knowledge) involves the shift of memory stores from short-term, working memory to long-term memory and the subsequent consolidation with previously acquired knowledge and transfer to a location independent of the medial temporal lobe system. The neocortex is presumed to play a significant, as yet undefined, role in the transfer of declarative memory from semi-permanent storage sites within the medial temporal lobe system to long-term storage sites, which can then be accessed and retrieved independently (Squire & Zola-Morgan, 1991). The remote declarative memory spared in medial temporal lobe amnesia is presumed to be that which has been transferred to this independent long-term storage site (Squire, 1987).

Anatomical substrate for procedural linguistic knowledge/memory

Procedural knowledge is generally considered to involve an aggregate of distinct skills which are acquired and stored in a number of distinct neuroanatomical systems (Squire, 1987; Harrington, Haaland, Yeo & Marder, 1990; Squire, Zola-Morgan, Cave, Haist, Musen & Suzuki, 1990; Bloedel, Bracha, Kelly & Wu, 1991). As discussed previously, the cerebellum and the basal ganglia may be responsible for the acquisition and orchestration of those procedural motor skills responsible for phonetic speech activity. Research involving the acquisition of the procedural skills underlying complex cognitive and linguistic activities has traditionally focused upon the cerebral cortex, but researchers have recently argued that the neocerebellum may also participate in the modulation, integration, and acquisition of these skills (Leiner, Leiner & Dow 1986, 1987, 1989, 1991; Schmahmann, 1991).⁷

The neocerebellum forms a significant portion of what researchers have identified as an extensive and phylogenetically enlarged "learning loop" (Leiner, Leiner & Dow, 1987). This proposed "learning loop" is essentially a circular neural circuitry system which connects the newly evolved regions of a number of brain structures including the cerebral neocortex, the neocerebellar

nuclei and cortex, and the red nucleus. The system is assumed to contribute substantially to the rapid and fluent acquisition and performance of procedural motor, cognitive, and linguistic skills in humans (Leiner, Leiner & Dow, 1986, 1987, 1989, 1991). The current proposal, which asserts that the neocerebellum is largely responsible for the acquisition of procedural linguistic skills, relies upon exactly these extensive connections with newly evolved regions of the human brain and areas of the cerebral cortex traditionally associated with language function, in addition to the cerebellum's enormous computational capacity. The proposed involvement of the neocerebellum and related neural circuitry in the acquisition of procedural linguistic skills will be discussed in detail in the section which follows.

PROPOSED MODEL OF PROCEDURAL LINGUISTIC SKILL ACQUISITION

The model of procedural linguistic skill learning presented here is based upon proposals made by Thompson (1984, 1986, 1989), Bloedel, Bracha, Kelly & Wu (1991), Ghez (1991), and Greenough & Anderson (1991) concerning cerebellar involvement in voluntary movement and motor skill learning. Current models of voluntary movement propose that the cerebellum is responsible for integrating the sensory input from the environment with the conceptual motor activity plans of the prefrontal association cortex and ultimately producing detailed, precisely timed and coordinated programs for the execution of motor activity which are then relayed to the relevant musculature by way of the motor neurons of the cerebral cortex (Ghez, 1991). Essentially, the model below proposes a similar involvement for the neocerebellum in the formulation and acquisition of (non-motor) linguistic programs. Although the cerebellum has not traditionally been assumed to play a significant role in the acquisition or production of language (aside from its strictly motor involvement in phonetic speech production), I suggest that it is in fact uniquely suited for its proposed role in the acquisition of procedural linguistic skills for several reasons. First, the cerebellar cortex contains an enormous number of neurons, similar to that of the cerebral cortex, enabling it to perform large quantities of precise computations quickly and accurately (Leiner, Leiner & Dow, 1987: 434). Second, because of the highly

structured, parallel organization of its dendritic and axonal networks which are easily and continuously modified by experience, the cerebellar cortex is capable of the immense quantities of high-speed parallel processing that are required for the acquisition and production of language.⁸ Finally, because of its ability to integrate incoming ascending sensory and descending cortical information with ongoing motor activities and its extensive connections with areas of the cerebral cortex implicated in language function (e.g. frontal and parietal association areas, prefrontal cortex, Broca's area, Wernicke's area, and motor speech cortex) the neocerebellum appears ideally suited to the task of orchestrating ongoing linguistic activity while acquiring or fine tuning novel procedural linguistic skills (Leiner, Leiner & Dow; 1986, 1987, 1989, 1991; Schmahmann, 1991).

Because the organization of information flowing into and out of the cerebellum is of central importance in understanding precisely how it might initially acquire and subsequently improve and refine performance of novel linguistic skills, I briefly summarize the relevant aspects of the neuroanatomical (structural) and neurophysiological (functional) organization of the neocerebellum below.

Anatomy and Physiology of the Neocerebellum

The cerebellum is located posterior to the pons and medulla and inferior to the cerebral hemispheres (cf., Figure 1). As a whole the cerebellum is responsible for the maintenance of equilibrium and balance, posture and muscle tone, and the initiation, coordination, and modulation of motor activities; responsibility for initiation and temporal coordination is presumably shared with the structures of the basal ganglia. The cerebellum is organized such that information from distinct functional systems (e.g., those devoted to equilibrium, posture, coordination) is directed towards different cerebellar nuclei and different regions of the cerebellar cortex for processing. Processed information and stimuli are then conveyed to related functional anatomical systems in other areas of the nervous system. In this manner functional systems are localized within specific regions of anatomical structures and yet distributed among networks of connections which span several anatomical systems.

The following description of the flow of information into and out of the cerebellum (Figure 2) is true of both the cerebellum as a whole and the region of primary concern to the current discussion: the neocerebellum.

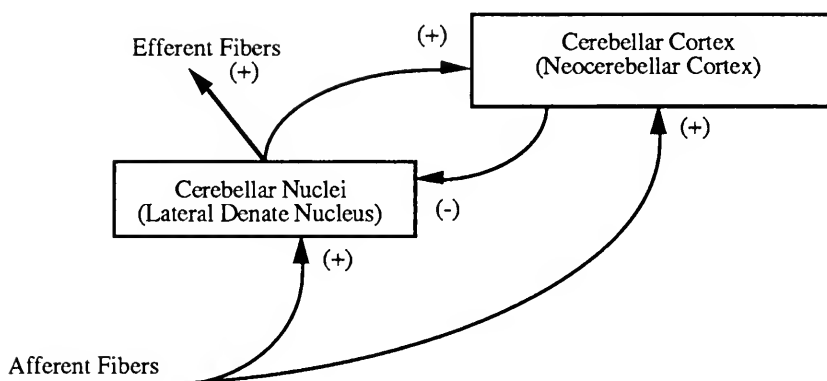


Figure 2. Highly schematized illustration of the flow of incoming and outgoing information in the cerebellum. Plus signs (+) represent excitatory connections, minus signs (-) inhibitory connections.

Information enters the cerebellum by way of large bundles of fibers (cerebellar peduncles) which ultimately terminate in predetermined regions of the cortex. En route to the cortex these afferent (incoming) fibers send branching (secondary) collateral fibers to the relevant cerebellar nucleus. Thus, the cerebellar nuclei and the cerebellar cortex are essentially responding to the same incoming stimuli but in a distinct manner. The efferent (outgoing) fibers of the cerebellar nuclei are excitatory in nature (i.e., they carry signals which facilitate activity), whereas the efferent fibers of the cerebellar cortex are inhibitory (i.e., they carry signals which inhibit or suppress activity). The efferent fibers from the cerebellar cortex all terminate in the cerebellar nuclei, suppressing the firing activities of those nuclei and indirectly suppressing motor activity. The efferent fibers from the cerebellar nuclei are the only fibers which actually leave the cerebellum and they fire under the modulating influence of the cerebellar cortical neurons. The fibers from the cerebellar nuclei ascend through the thalamus to terminate in predetermined regions of the cerebral motor cortex (Brodmann's areas 4 & 6) and convey impulses which stimulate the firing activity of the cortical motor neurons. The motor neurons of the cerebral cortex are responsible for conveying the excitatory stimuli to the musculature which result in motor activity. Thus, although the excitatory stimuli which ultimately result in motor activity originate

in the cerebellar nuclei, these impulses can be directly suppressed by the inhibitory impulses of the cells of the cerebellar cortex.

afferents to the neocerebellum: Two important sources of afferent (incoming) fibers to the neocerebellum are the fibers descending from the cerebral cortex (via the corticopontocerebellar tract) and the fibers originating in the olivary nucleus. These tracts connect the neocerebellum with several cortical structures implicated in language function including: the frontal cortical association areas (abstract reasoning and planning), prefrontal cortex (planning and monitoring), Broca's expressive speech area (areas 44 & 45), motor speech cortex (areas 4 & 6) and Wernicke's receptive speech area (areas 22 & 42). The corticopontocerebellar tract consists of efferent fibers originating in each of the four lobes of the cerebral cortex which descend through the pontine nuclei and decussate (i.e., cross) to enter the contralateral cerebellar hemisphere. In this manner the right cerebellar hemisphere receives information regarding the activities of the right side of the body from the left cerebral hemisphere, and the left cerebellar hemisphere from the right cerebral cortex. The climbing fibers from the olivary nucleus constitute a second source of afferent fibers to the neocerebellum. The significance of these fibers is twofold. First, the olivary nucleus receives the majority of the efferent fibers from the red nucleus which is a brainstem structure receiving massive projections from the neocortex. Second, the cells of the red nucleus are reported to exhibit remarkable plasticity (Tsukahara, 1984). As previously mentioned, researchers have speculated that the red nucleus may play a considerable role in a newly evolved and enlarged learning loop within the human brain (Leiner, Leiner & Dow, 1986). A third important source of afferent fibers are those of the ascending spinal tracts. These fibers convey sensory and proprioceptive (related to position and movement of muscles) information from the external environment and the musculature directly to the cerebellum. It is this continuously up-dated information concerning the changing environment and ongoing motor activity which enables the cerebellum to effectively monitor and orchestrate smooth and balanced movement.

efferents from the neocerebellum: As discussed above, efferent fibers from the neocerebellar cortex terminate exclusively in the lateral dentate nucleus, which in turn serves as the unique source of efferent fibers leaving the neocerebellum. A small percentage of efferent fibers from the dentate nuclei return to the cerebellar cortex

forming a circular feedback loop crucial to the cerebellum's function in continuously monitoring and modifying ongoing activity. However, the majority of the efferent fibers from the dentate nucleus leave the cerebellum and project to the thalamus (ventral lateral and ventral anterior nuclei). The efferent fibers from these thalamic nuclei subsequently project to diverse regions of the cerebral cortex including: the frontal motor areas of the cerebral cortex (areas 4 & 6), the prefrontal cortex (area 8), the frontal association cortex, Broca's expressive speech area (areas 44 & 45), and Wernicke's receptive speech area (areas 22 & 42) (cf. Figure 1).

In summary, the neocerebellar cortex and the dentate nuclei receive identical stimuli from the cerebral cortex and the environment, enabling the dentate nuclei to respond directly to sensory, proprioceptive, and cerebrocortical stimuli while simultaneously being monitored and influenced (i.e., inhibited) by the neurons of the neocerebellar cortex. The information conveyed to the neocerebellum from the cerebral cortex includes stimuli from several areas with identified language related functions including the frontal cortical association areas involved in abstract reasoning and planning, the prefrontal cortex responsible for planning and monitoring, Broca's expressive speech area, the motor speech cortex, and Wernicke's receptive speech area. Given its extensive, highly organized and neuron-dense networks, the neocerebellar cortex is able to process the incoming information at high speeds. It then performs the computations required to integrate input from the cerebrocortical, sensory, and motor systems and produce a detailed program for the execution of the desired linguistic behavior. On the basis of this program, the neocerebellar cortex is then able to monitor, in an "informed" manner, the firing of the dentate nuclei which ultimately (by way of the thalamus) convey excitatory stimuli to the motor neurons of the cerebral cortex resulting in the motor activity of the speech organs. Thus, although the signals conveyed to the cortical motor neurons originate in the cells of the dentate nuclei, the firing of these cells is crucially guided by the activity of the neurons of the cerebellar cortex, which are thereby capable of determining the outcome of motor speech activity by suppressing (inhibiting) undesired behaviors and allowing (disinhibiting) desired behaviors.

Model of Procedural Linguistic Skill Acquisition

The model presented here proposes that procedural linguistic skill acquisition occurs essentially as follows. To begin, general

linguistic plans or behavior structures regarding desired future linguistic activity are sent to the cerebellum from the expressive speech area of the cerebral cortex (Broca's area) and, presumably under the guidance and monitoring influence of the prefrontal cortex, they are operationalized within the neocerebellar cortical networks and the related neural circuitry (Figure 3).⁹ The operationalization of these general, conceptual linguistic plans or behavior structures involves extensive and high-speed parallel processing and the integration of motor and cognitive activities, and results in the production of detailed, precisely timed programs for the execution of linguistic activity. The newly created programs are then relayed back to the expressive speech region of the cerebral cortex and can ultimately be used to orchestrate and oversee motor speech activity. During the acquisition process on-going linguistic activity is monitored and evaluated by the neocerebellum and the prefrontal cortex, and information concerning the relative success or failure of the performance of the novel skill is used to create appropriate cognitive and linguistic plans for future action and to help direct focused attention to aspects of the developing program which require improvement and fine-tuning. Subsequent performances of the novel skill result in gradual and incremental long-term gains in the accuracy of the cerebellar program and the speed with which it is executed.

In such a model, the role of the prefrontal cortex would be most essential during the early stages of skill acquisition when the novel linguistic plans are first conveyed and refined into detailed, precisely timed cerebellar programs for linguistic activity. In fact, this assumption is generally in accordance with what is known about the involvement of the prefrontal cortex during the acquisition of novel skills. Fuster (1992) reviews a large body of clinical and experimental evidence which suggests that "the prefrontal cortex is essentially involved in the formation of behavior structures" and of crucial importance when those behavior structures are either "novel to the organism or unusually complex in their sensory or motor aspects" (Fuster, 1988, 1992: 352). Research also suggests that frontal cortical planning activities may be responsible for ensuring that attention is directed towards selected aspects of the incoming linguistic and sensory information (Lem, this volume) enabling input to be transformed into intake (Sato & Jacobs, this volume), and may result in what is experienced by the learner as consciousness (cf. Bridgeman, 1992). According to the proposed model, once the neocerebellum has successfully acquired (i.e.,

language, or any other complex cognitive skill, requires the gradual integration of the individual sub-components of a complex skill which occurs over time as processes that were initially "controlled" (i.e., highly cognitively demanding) become "automatized" (i.e., less cognitively demanding) (Faerch & Kasper, 1985; McLaughlin, 1987). Attempting to apply the current neurobiological framework to cognitive theories of acquisition, "controlled" processes can be equated with procedural linguistic skills in the process of being acquired, still requiring frontal cortical monitoring to ensure accurate performance, and "automatic" processes with procedural skills which have been fully acquired (i.e., operationalized and refined) and are executed within the circuitry of the cerebellum and related neural systems without prefrontal involvement. Inconsistencies observed in the performance of skills being acquired are therefore considered a result of the limited capacities of the prefrontal region of the cerebral cortex, which can only plan for and direct focused selective attention to a limited number of tasks at one time.

Stages in the Acquisition of a Procedural Skill

The neurobiological process of acquiring a procedural linguistic skill is a gradual and incremental one which, according to the current model, involves three stages: formulation, evaluation, refinement (Table 1).

Formulation: As suggested by this model, the initial acquisition stage begins when the general cognitive and conceptual linguistic plans that serve as a model of desired activity or behavior is first conveyed to the cerebellum from regions of the prefrontal and frontal cortex and Broca's expressive speech area. This stage involves the integration of desired linguistic behaviors with incoming sensory information concerning the external environment and on-going activity. During this initial formulation stage, the dense networks of the cerebellar cortex and the circuitry involving related neural systems are assumed to perform the computations necessary to operationalize general cortical linguistic plans and to produce a detailed, precisely timed program for the execution of linguistic activity.

Evaluation: During the evaluation stage the developing program is presumably conveyed back to Broca's area and ultimately results in motor speech output which is closely monitored by both the

Table 1:
Procedural Skill Acquisition Stages

Formulation:

—General cognitive and conceptual linguistic plans for future action conveyed to cerebellum from Broca's area and prefrontal and frontal association cortex;

—Integration, processing and computation of information in neocerebellar circuits and related neural systems (e.g., basal ganglia);

—Formulation of detailed execution program for linguistic activity.

Evaluation:

—Execution of program with simultaneous monitoring and evaluation of actual performance, as compared with desired behavior within the cerebellar circuitry and the prefrontal cortex;

—Using information concerning relative success or failure in execution, the prefrontal cortex responds with new plans for future activity designed to improve performance and inform direction of selective attention to relevant linguistic features of input/output.

Refinement:

—Subsequent performances of skill benefit from updated prefrontal planning and enhanced perception of relevant linguistic features involved in execution;

—Detailed program gradually becomes more accurate and coordinated;

—Requirements of cortical planning and selective attention to the task decrease, and frontal association cortex and attentional systems gradually cease involvement during the execution of the skill.

cerebellum and the prefrontal cortex. The continuous monitoring of the on-going activity and comparison with the desired behaviors which occurs within the cerebellum and the prefrontal cortex result in an evaluation of the relative success of initial attempts to perform the novel skill. Based upon this evaluation, the prefrontal cortex can then respond by generating appropriate plans for future action designed to improve subsequent performance and direct attentional

systems to focus selected attention on relevant features of the linguistic input/output.

The evaluation and ensuing plans may be communicated to and stored within the medial temporal lobe system, resulting in a declarative memory of the learning experience and/or explicit knowledge of one's strengths and weaknesses with respect to the skill being acquired (Kleiter & Schwarzenbacher, 1989). This explicit declarative knowledge related to the acquisition process may prove to be invaluable to the speaker/learner's effective use of cognitive and metacognitive learning strategies and may serve as the primary basis upon which they judge their relative success or failure as learners.¹¹

Refinement: Finally, during the refinement stage, the updated cognitive and linguistic cortical plans can serve to facilitate the subsequent refinement and debugging of the execution programs of the cerebellum. The gradual improvement and fine-tuning of the cerebellar execution programs during the refinement stage of acquisition can then result in long-term gains in the speed, consistency, and accuracy of the performance of the newly acquired procedural skill. The gradually increasing accuracy and ease with which the skill is executed by the neocerebellar circuitry accounts for the decreasing involvement of prefrontal cortical monitoring activity results in a gradually fading conscious awareness of, and focussed attention during, performance of the procedural linguistic skill.

SUPPORT FOR THE PROPOSED MODEL

PET Studies

Research conducted with positron emission tomography (PET) imaging technology has attempted to identify the neural structures activated during the performance of a limited subset of linguistic functions: semantic word association tasks (Raichle, 1990; Peterson, Fox, Posner, Mintun & Raichle, 1989). By asking subjects to (1) look at or listen to a word, (2) say that word aloud, and (3) provide another word which was semantically associated in a predetermined manner to the original word, researchers were able to identify the neuroanatomical systems actively involved in the linguistic task of semantic association. In addition, by tracking the brain activity of subjects over time they were able to distinguish

between those structures presumably responsible for performance of the linguistic skill of word association and those involved only in the acquisition of the skill. The results of these PET studies confirm a role for the neocerebellum in procedural linguistic activity which is distinct from its traditionally assigned motor speech role. The right lateral portion of the neocerebellum was active during both the initial acquisition and the subsequent performance of the word association task. Significantly, the right hemicerebellum communicates with the left (language dominant) cerebral hemisphere, further suggesting that the neocerebellum is actively involved in specifically linguistic functions. Regions of the frontal cerebral cortex and the anterior cingulate gyrus (implicated in focused selective attention) were also actively involved during the acquisition phase but, significantly, were not involved in later performance of the task. These findings, although far from conclusive, are consistent with the current proposal that the planning and monitoring activities of the frontal association cortex and the selective attentional capacity of the anterior cingulate gyrus are required only during the acquisition process when the task is novel and requires focussed selective attention, whereas the activity of the neocerebellum is involved throughout the acquisition process and required for execution even after the skill has been successfully acquired.

William's Syndrome

Research conducted on patients with William's Syndrome provides additional support for the proposed role of the neocerebellum in the acquisition and execution of procedural linguistic skills (Bellugi, Bihrlé, Jernigan, Trauner & Doherty, 1990). William's Syndrome (WS) is a rare neurological disorder which is characterized by a marked reduction in cerebral volume (80% of normal size) with no significant reduction in cerebellar volume (99% of normal). When compared with age and IQ matched Down's Syndrome (DS) subjects, WS subjects performed significantly better on linguistic tasks, demonstrating remarkably preserved syntactic abilities (Bellugi, Bihrlé, Jernigan, Trauner & Doherty, 1990: 117). These results are perhaps even more striking in light of the fact that DS subjects show significant reduction in both cerebral (77% of normal) and cerebellar (69% of normal) volume. Researchers have speculated that the remarkable preservation of formal linguistic abilities in WS subjects in contrast to the general retardation of their other cognitive capacities may be a reflection of the concurrent reduction in cerebral volume and relative

preservation of cerebellar volume, assuming of course that the cerebellum plays a significant role in linguistic function (Bellugi, Bihrlé, Jernigan, Trauner & Doherty, 1990; Leiner, Leiner & Dow, 1991).¹²

Deficits Associated with Cerebellar Lesions

Evidence is accumulating from lesion studies that damage restricted to some regions of the cerebellum does not result in the typically observed motor deficits, but instead in significant cognitive impairment (Leiner, Leiner & Dow, 1987, 1989, 1991). In one study five patients with cerebellar damage were reported to demonstrate substantially impaired performance on almost all tests administered when compared with ten control subjects (Bracke-Tolkmitt *et. al.*, 1989). Significantly, subjects with cerebellar damage were impaired on all measures of IQ, including both verbal IQ and general ability (Bracke-Tolkmitt *et. al.*, 1989: 443). Thus far, there have been no reports of significant, specifically linguistic (non-motor) impairments as a result of cerebellar damage. However, given what is known of the diffuse and distributed nature of memory representation in the cerebellar circuitry, generalized impairment of formal linguistic capacities would require rather extensive cerebellar lesions and would most likely result in damage to motor and general cognitive capacities as well.

IMPLICATIONS OF THE PROPOSED MODEL: DECLARATIVE "LEARNING" AS A METACOGNITIVE STRATEGY FOR PROCEDURAL LINGUISTIC SKILL ACQUISITION

SLA researchers have, for many years, debated the questions of whether, to what extent, and in precisely what manner language teachers ought to incorporate formal, explicit grammar instruction into their ESL curriculum (see Celce-Murcia, 1992 and Krashen, 1992 for current perspectives on this debate). The current proposal can contribute to a future resolution by offering a new conceptualization of the problem, in addition to a potential, if only partial, solution. Although, as Celce-Murcia (1992) asserts, formalized grammar instruction is probably essential if post-pubescent adolescents and adults are to ever acquire near-native linguistic competence in an L2 and must be embedded within the

meaningful and contextualized use of language, there remains significant skepticism regarding the limited usefulness of such instruction.

Krashen (1992), for instance, concludes that because of the fundamental distinction between conscious "learning" and unconscious "acquisition" processes, the effects of formal grammar instruction are unavoidably destined to be "peripheral and fragile". However, McLaughlin (1990) contends that the notion of consciousness is entirely too vague to be of much use in theories of SLA and should be avoided in favor of more strictly defined concepts such as automatic and controlled processes and restructuring.

I propose that considering these facts from a neurobiological perspective might provide both new insight into the nature of the problem and a potential conceptual framework within which to develop a solution. Essentially, I suggest that traditional approaches to formalized grammar instruction may have proved of limited usefulness because they generally resulted in students acquiring declarative knowledge related to procedural linguistic skills rather than the procedural linguistic skills themselves. Although explicit declarative knowledge of the L2 linguistic system may be useful when taking a written exam or consulting a pedagogical grammar text, this type of knowledge is an insufficient basis for the fluent and spontaneous use of the L2 for communicative purposes. What has yet to be determined is how formalized grammar instruction can be effectively incorporated into ESL curriculum so as to facilitate learner's acquisition of procedural linguistic skills.

Although the neurobiological theories of learning and memory presented above support the claim that declarative knowledge (i.e., "learning") cannot be directly transformed into procedural skills (i.e., "acquisition"), they do not preclude the possibility that the prior acquisition of related declarative knowledge may under restricted circumstances serve as an effective metacognitive strategy to enhance the subsequent acquisition of procedural linguistic skills (cf. O'Malley & Chamot, 1991). The term metacognitive strategy is intended to refer to a strategy for learning which involves conscious, implicit consideration and planning related to the learning process itself. The above scenario is possible only if the declarative knowledge related to the novel procedural linguistic skill is used to inform and improve the planning and monitoring activities of the prefrontal cortex and to enhance the direction of focussed selected attention to the relevant features of the linguistic system in both the environmental input and

the behavioral output. The contribution of explicit declarative knowledge of the L2 linguistic system to the successful acquisition of procedural linguistic skills thus lies in its potential contribution to the learner's use of effective metacognitive strategies to facilitate the learning process itself. This contribution, however, requires active and informed involvement on the part of both the L2 learner and the language instructor in the development and use of cognitive and metacognitive learning strategies as well as a general level of awareness regarding the nature of learning itself. The intentional and strategic use of declarative linguistic knowledge in the process of acquiring a second language as an adult has also been advocated on independent grounds by other researchers including Celce-Murcia (1992), Wenden (1991), and Widdowson (1990).

CONCLUSION

In this paper, I have presented a model of procedural skill acquisition which crucially involves the circuitry of the neocerebellum, Broca's area, and regions of the frontal and prefrontal cerebral cortex. This model, although it remains largely speculative, is a plausible neurobiological account of the acquisition of procedural linguistic skills and offers a potential means of unifying competing cerebral and cerebellar theories of language function. In addition, the model provides a conceptual framework for further investigation of the potential facilitatory contribution of explicit, formally learned declarative linguistic knowledge to the successful acquisition of procedural linguistic skills. However, much remains to be done in terms of clarifying and more precisely characterizing the neurobiological processes involved, more thoroughly addressing the nature of the linguistic knowledge and its representation, and incorporating pragmatic and discourse related knowledge.

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NOTES

¹ I have chosen to focus on adult SLA, rather than PLA, to avoid the confounding influences of neurological and cognitive development.

² See Pinker & Prince, 1988 for additional discussion of the linguistic processes involved in pluralization.

³ Ojemann himself acknowledges that subcortical structures such as the thalamus are likely to be involved in linguistic function (Ojemann, 1991).

⁴ See Bialystok, 1990 for discussion of the benefits of such a compromise.

⁵ Brodmann's areas are a numerical representation of designated regions of the cerebral cortex devised by Brodmann (1909).

⁶ Dative alternation refers to the movement of the indirect object (IO) of a small class of verbs such as "give" to a preposition-less position immediately following the verb as an alternative to the IO appearing as the object of a preposition following the direct object.

⁷ The neocerebellum is the most recently evolved portion of the cerebellum and comprises the posterior and lateral portions of the cerebellar cortex and the lateral dentate nucleus.

⁸ See Loritz, 1991 for discussion of the demand for parallel, rather than serial, processing.

⁹ No assumptions are made concerning the origin of these linguistic commands. It is conceivable that they are either predominantly learned (i.e., abstracted from the incoming linguistic data perhaps by regions of frontal association cortex) or predominantly innate (i.e., unlearned principles and parameters of Universal Grammar). For detailed discussion of this topic see Jacobs (1988), Crain (1991), and Jacobs & Schumann (1992).

¹⁰ See Levelt, 1978, 1989, for a hierarchy of communicative goals.

¹¹ See O'Malley & Chamot, 1990 for discussion of effective use of learning strategies in SLA.

¹² An alternative explanation might be that WS subjects, unlike DS subjects, have an essentially intact perisylvian cortex and thus display preserved linguistic abilities.

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Scarlett Robbins is a Ph.D. student in the Applied Linguistics program at UCLA. She holds an M.A. in Linguistics from the University of California, Santa Cruz. Her research interests include: first and second language acquisition, the neurobiology of memory and learning, and phonology.

From Input to Intake: Towards a Brain-Based Perspective of Selective Attention

Edynn Sato and Bob Jacobs
University of California, Los Angeles

Anatomy is destiny.
(Freud, attributed)

From a neurobiological perspective, the present paper addresses (1) the input-intake distinction commonly made in applied linguistics, and (2) the role of selective attention in transforming input to intake. Primary emphasis is placed on a neural structure (the nucleus reticularis thalami) that appears to be essential for selective attention. The location, connections, structure, and physiology of the nucleus reticularis thalami are examined to illustrate its critical role in information processing. By orchestrating the selection and enhancement of relevant sensory input, the nucleus reticularis thalami acts as a "conductor" of neural systems involved in learning. It is argued that investigations of brain structures such as the nucleus reticularis thalami provide a more fundamental understanding of language acquisition mechanisms.

INTRODUCTION

First and second language learners must interact with the environment to acquire the target language. Interaction with the external milieu continually shapes the internal milieu supporting the mental systems of language, cognition, and social meanings (Hatch & Hawkins, 1987). In the neurobiological perspective adopted by the present paper, language is viewed as a multimodal sensory enhancement system (Jacobs, 1988), that is, a system that depends

on the primary senses (i.e., audition and vision) for the linguistic *and* contextual information they bring into the brain, where meaning is derived by comparing incoming sensory information with extant neural structures formed by experience. Learning, including language learning, thus involves the experience-dependent generation or modification of enduring internal representations (Dudai, 1989; cf. Jacobs & Schumann, 1992).

The interaction between the learner and the environment not only takes place in the context of an "action dialogue" (Bruner, 1975, p. 284), but also within a localized situational and larger socio-cultural context (cf. Ochs, 1982; Ochs & Schieffelin, 1984; Schieffelin & Ochs, 1986; Ochs, 1988; Schieffelin, 1990). Language learners are continually exposed to far more information than they can possibly process. Thus, a major concern for language acquisition researchers is how language learners selectively attend to information in the environment, that is, how *input* becomes *intake*. From a neurobiological perspective, the present paper first discusses the distinction between input and intake that is commonly made in applied linguistics. Because the input-intake distinction is intimately related to the concept of selective attention, we briefly explore the role of selective attention in modulating information flow. Finally, we attempt to provide a more fundamental understanding of selective attention by presenting a neural structure that appears to be involved in transforming input into intake.

INPUT AND INTAKE: THE NEED FOR SELECTIVE ATTENTION

In second language acquisition (SLA), input and intake are characterized as both objects/products and processes. When input is characterized as an *object*, it may be equated with the source of information to which the learner is attending. This source of information cannot be limited to exposure of a linguistic nature because, even though a great deal of sensory information is ignored or discarded as irrelevant by the brain, it is never clear exactly what the individual is perceiving. When input is characterized as a *process* (Young, 1988), it appears to overlap with the psychological constructs of *comprehensible input* (Krashen, 1981, 1982, 1985) and *intake* (Corder, 1967), which have been hypothesized to "explain" how learners "internalize" the linguistic patterns available in the input. These constructs are presumed to account for the

portion of the input that actually makes it into the learner's head as an organized and retrievable form of knowledge. The *i* in Krashen's well-known metaphor, *i + 1*, is an attempt to characterize the state of the learner's brain at a given point in acquisition, but it has been severely criticized for failing to explain the acquisition "mechanisms" involved (Gregg, 1984). Chaudron (1985) has elaborated on these "mechanisms" by suggesting that intake is a complex process (rather than a product) involving the perception and encoding of input, followed by integration of linguistic information into the developing grammar.

As helpful as these attempts to describe input and intake may be, they remain abstract characterizations of learner behavior and, as such, reveal nothing of the underlying mechanisms involved (Jacobs & Schumann, 1992). The present neurobiological perspective attempts to describe underlying *neural* mechanisms responsible for processing input and intake. Thus, in the present perspective, *input* is viewed as the *object* of the learner's attention and *intake* is viewed as the *product* of information processing in the brain, which is discussed below.

Selective attention: Modulating information flow

Language learning requires that the brain's processing systems have access to relevant input. This is accomplished through selective attention, a phenomenon whereby an individual directs attention towards and maintains attention on the stimuli of relevance. The present section will describe selected conceptualizations of the attentional process: the neurobiological concepts of early and late selection, and the psychological concepts of bottom-up and top-down processing.

Neurobiologically, meaning is constructed from the interaction of sensory information (i.e., the "external context") with prior knowledge as it is organized in the brain (i.e., the "internal context") (Jacobs, 1991). It is the internal context that influences an individual's selective attention and subsequent understanding of input. Presently, there is disagreement about how the internal context influences selective attention because, theoretically at least, its influence may be manifested in one of two ways: early selection or late selection. With regard to early selection, the internal context restricts the capacity for sensory processing, necessitating a "filtering" of input based on simple characteristics of the stimulus, prior to semantic encoding (Broadbent, 1958; Edelman, 1989; LaBerge, 1990; Mangun & Hillyard, 1990; Corbetta, Miezin,

Dobmeyer, Shulman & Petersen, 1991). With regard to late selection, the internal context sets no limit on sensory processing, allowing selective attention to occur simultaneously with or following semantic encoding (Edelman, 1989; Mangun & Hillyard, 1990; Corbetta et al., 1991). Whether it occurs early or late, selective attention is the outcome of multiple mechanisms mediating action directed toward achieving goals or satisfying criteria set by the individual's internal context (Treisman 1960; Treisman & Gelade, 1980; Crick, 1984; Allport, 1987; Neumann, 1987; Edelman, 1989).

Psychologically, there are two Vygotskian based theories for how patterns in stimuli may be recognized and sensory events are given meaning: bottom-up processing and top-down processing (Rogoff, 1990). Bottom-up processing suggests that a new stimulus is examined by its basic elements or features. This processing is "bottom-up" because the stimulus must be analyzed into specific features or building blocks before being assembled into a meaningful pattern. Top-down processing examines a stimulus, not by discrete feature analysis, but by rapid pattern organization, making use of situational context. Both neurobiologically and psychologically, learning thus begins with a perception and focused attention on a stimulus.

Although psychological theories and information processing models have made significant progress in explaining the role of selective attention in learning (Shiffrin & Atkinson, 1969; Craik & Lockhart, 1972), they cannot adequately explain *how* one attends to appropriate stimuli nor do they address the neural mechanisms involved in selective attention. However, a brain-based model can. Just as Krashen's (1985) "affective filter" has found neural correlates in the work of Schumann (1990, 1991), selective attention appears to fall within the domain of a neural structure known as the nucleus reticularis thalami (NRT). The following section describes the NRT and discusses its involvement in selective attention.

A PUTATIVE BRAIN STRUCTURE FOR SELECTIVE ATTENTION: THE NUCLEUS RETICULARIS THALAMI

Numerous networks involved in selective attention have been identified (Posner, Inhoff, Friedrich & Cohen, 1987; Robbins & Everitt, 1987; Desimone & Ungerleider, 1989; LaBerge, 1990; Mangun & Hillyard, 1990; Posner & Peterson, 1990; Corbetta et al., 1990, 1991; Cohen & Rafal, 1991). However, it remains unclear how these multiple systems work in concert. Although the present paper will not elaborate on the cohesion of this "cerebral symphony" (Calvin, 1989), it will discuss a neural structure that seems to function as its "conductor," coordinating the expression and salience of the various instruments in this orchestra. The "conductor" is the nucleus reticularis thalami (NRT).

The NRT is part of the thalamus, a structure through which all sensory information, with the exception of olfaction (= the sense of smell), must pass before being further processed in the region of the brain known as the cerebral cortex (Figure 1). The NRT's involvement in selective attention is not surprising because it appears to share both morphological and functional characteristics with the brainstem reticular formation (BRF), a diffuse collection of neurons with far-reaching connections throughout the brainstem.¹ Morphologically, NRT neurons (= nerve cells) resemble those of the BRF in terms of size and general branching patterns (Carpenter & Sutin, 1983). Functionally, both NRT and BRF neurons are involved in arousal (Carpenter & Sutin, 1983; Scheibel, 1984). The BRF responds to sensory stimulation and, via pathways that ascend through the brainstem to the cortex (in particular the lemniscal and the ascending reticular activating systems), exerts its influence over broad areas of the cortex, evoking arousal responses (Carpenter & Sutin, 1983). En route to the cortex, the ascending pathways project upon (= make connections with) regions of the thalamus and thus involve the NRT (Carpenter & Sutin, 1983, Steriade, Jones & Llinás, 1990).

To illustrate the NRT's role in selective attention, the following sections sequentially discuss its (1) location, (2) connections, (3) structure, and (4) physiology. The location and connections of the NRT underscore its essential involvement in selective attention. How the NRT participates in selective attention becomes clear when one examines its structure and physiology.

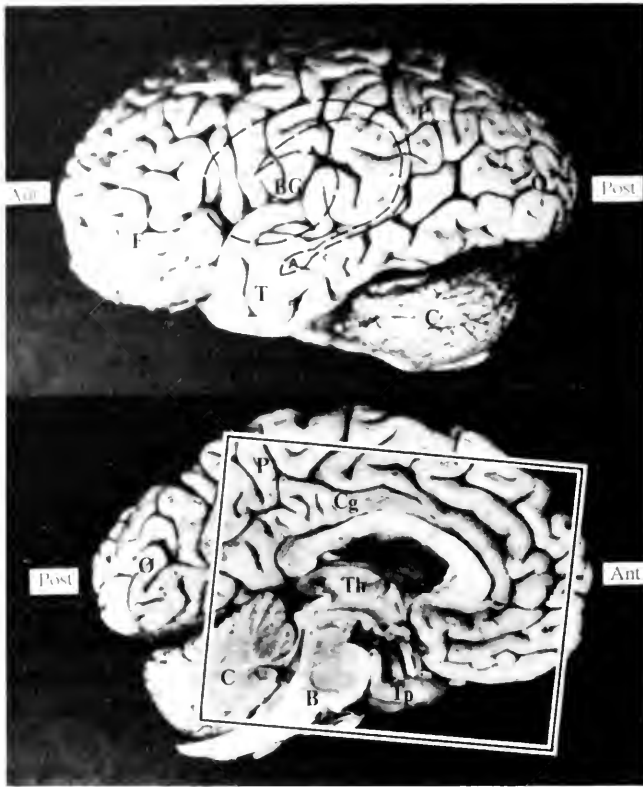


Figure 1. Photographs of the left hemisphere of the human brain. Lateral (top photo) and medial (bottom photo) views demonstrate the relative position of the cerebellum (C) and the four major lobes of the cerebral cortex: frontal (F), parietal (P), occipital (O) and temporal (T). In addition to these regions, the lateral perspective illustrates the relative position of the basal ganglia (BG) and amygdala (A), both of which are deep to the cerebral cortex. The medial perspective reveals the relative position of the thalamus (Th), cingulate gyrus (Cg), brainstem (B), and the temporal lobe (Tp). Running throughout the brainstem is the diffuse network of cells known as the brainstem reticular formation (BRF) (not shown). The framed area in the medial view outlines the portion enlarged for Figure 2. Ant = Anterior, Post = Posterior.

Location

As mentioned earlier, language acquisition is dependent on the primary senses (i.e., audition and vision) for bringing linguistic and contextual information into the brain. All sensory information entering the brain, with the exception of olfaction, passes through the thalamus, where it is associated and synthesized, before proceeding to the cerebral cortex. The cerebral cortex, which processes and responds to sensory information, is traditionally divided into four major regions, or lobes, each of which serves a specific processing function (Figure 1). In order for sensory



Figure 2. Enlarged view of the medial surface of the human brain as framed in Figure 1. This perspective highlights, somewhat schematically, the position of the nucleus reticularis thalami (NRT) on the dorsal portion of the thalamus. By virtue of its position in the center of information flow, all incoming sensory impulses (e.g., from the cerebellum and through the brainstem) must pass through the thalamus and the NRT en route to the cerebral cortex (single headed arrows). There is continual two-way communication between the cerebral cortex and the thalamus (double headed arrows), all of which also passes through the NRT.

information to reach appropriate areas of the cortex, it must be directed there. The thalamus serves this function.

The thalamus consists of several nuclei, or groups of cells sharing the same function. One of these nuclei is the NRT, a sheet-like complex of cells enveloping thalamic nuclei committed to sensory and associative functions (Scheibel & Scheibel, 1966; Jones, 1975, 1985; Skinner & Yingling, 1977; Angel, 1983; Avanzini, de Curtis, Panzica & Spreafico, 1989). As shown in Figure 2, all connections from the thalamus to the cortex (thalamocortical) and back (corticothalamic) pass through the NRT (Jones, 1985). By virtue of its location, the NRT is intimately involved in the modulation of all communication between the thalamus and the cortex. It constitutes a high resolution organic "screen" capable of monitoring and modulating thalamo-cortico-thalamic interactions (Scheibel & Scheibel, 1966), a "screen" that preferentially enhances certain aspects of stimuli and simultaneously attenuates the salience of other input.

Connections

Information is organized topographically in the central nervous system (CNS), which consists of the brain and the spinal cord. In other words, external stimuli are mapped onto the CNS in an orderly fashion. Auditory impulses are mapped tonotopically (i.e., frequency relationships between sounds are preserved from the cochlea of the inner ear to the auditory cortex). Visual stimuli are organized retinotopically (i.e., visual field images on the retina are transferred faithfully to the visual cortex). Tactile and motor information are represented somatotopically (i.e., the relationships between parts of the body are maintained in CNS representations). The brain's topographical organization permits sensory information to be processed efficiently in circumscribed networks dedicated to a particular type of information. The NRT also adheres to a general topographical organization (Jones, 1975, 1985), which helps it to direct in an orderly manner the enormous amount of sensory information ascending to the cortex. The NRT's topographical relationship with the thalamus and cortex is evidenced by the constant, relatively circumscribed regions of the NRT through which thalamocortical and corticothalamic fibers of particular thalamic nuclei cross (Steriade et al., 1990). Regions of the NRT are thereby associated with a thalamic nucleus or group of nuclei (primarily in the upper-most or dorsal portion of the thalamus) and hence a sensory or functional system (Steriade et al., 1990). As

thalamocortical and corticothalamic fibers pass through the NRT, the NRT is capable of influencing information flow. The NRT works as a "gating mechanism" (see below), permitting (i.e., selecting) passage of specific information for further processing (Skinner & Yingling, 1977; Yingling & Skinner, 1977; Scheibel, 1987; Steriade et al., 1990).

Regions of the NRT that may be involved with language are implicated in research conducted by Ojemann (1975, 1976, 1984). Using electrical stimulation of the human brain in patients undergoing surgery for intractable epilepsy, Ojemann identified specific areas of the thalamus involved with language, arousal, and verbal memory. Projecting a series of slides on a screen, Ojemann tested his subjects' ability to name and recall objects while electrically stimulating areas of the thalamus. Electrical stimulation acts as a temporary, reversible lesion that helps identify structures involved in a particular function. Four basic types of language disturbances resulted from this stimulation: arrest of speaking, anomia, perseverance, and repetition.² These dysfunctions were identified by stimulation of discrete areas of the left thalamus (especially the ventrolateral portion). Within this context, the NRT theoretically acts as a modulator of nerve impulses conducted through thalamocortical fibers (axons) originating in the left ventrolateral thalamic nuclei. The nerve signals passing through the NRT are believed to prime the cortex of the left hemisphere for incoming, linguistically relevant information (Ojemann, 1975).

Many structures besides the cortex are involved in learning. Four structures are of particular interest: (1) the hippocampus, (2) the cerebellum, (3) the basal ganglia, and (4) the cingulate gyrus (Edelman, 1989; Seib, 1990). The *hippocampus*, which is located deep within the temporal lobe, consolidates recently acquired information and is involved in laying down new memories, including spatial and episodic memory (Edelman, 1985; Rolls, 1990; Kandel, Schwartz & Jessell, 1991). The NRT may assist the hippocampus by focusing and maintaining attention on relevant stimuli.

The NRT may similarly facilitate *cerebellar* processing. Traditionally the cerebellum (shown in Figure 1), which sends information to the cortex via the thalamus, has been recognized for its involvement in motor coordination. More recently the cerebellum has been implicated in cognitive functions such as the learning of rote memories (Edelman, 1989; Schmahmann, 1991; Robbins, this volume). To cite one example, Petersen, Fox, Posner, Mintun and Raichle (1989) monitored subjects performing a semantic

association task. The task required subjects to generate a semantically-associated verb for a series of nouns. Using Positron Emission Tomography (PET), an imaging technique yielding anatomical-functional correlations, they discovered activation (i.e., increased activity and therefore greater processing demand) in regions of the cerebellum distinct from areas involved in motor tasks. These results strongly suggest "cognitive" functions be added to the cerebellum's well-known sensory and motor repertoire. The *basal ganglia*, which consist of several substructures (caudate, putamen, globus pallidus, amygdala, and claustrum), serve an associative function, connecting sensory and conceptual categorization with motor responses (Edelman, 1989) (Figure 1)³. Many basal ganglia interconnections with the cortex are mediated by the thalamus. With a passive presentation of visual words, Petersen, Fox, Posner, Mintun, and Raichle (1989) found that an area of the basal ganglia (the left lateralized area, possibly the putamen) was activated. They concluded that the basal ganglia may be involved in lexical or letter level processing. The NRT may influence processing in the basal ganglia by indirectly modulating information traveling between the cortex and the basal ganglia (particularly to the putamen and caudate nucleus) (Carpenter & Sutin, 1983).

The NRT also works in concert with the *cingulate gyrus*, which is part of a somewhat diverse collection of brain areas known as the limbic system (Figure 1). The limbic system contributes to emotion, memory, and the coordination of value-dependent states (Kandel et al., 1991; LeDoux, 1992). Petersen and colleagues (1989) suggest that the cingulate gyrus may be involved in response selection. Subjects were asked to perform two tasks: the "generate uses" and the "semantic monitoring" tasks. The generate uses task required subjects to utter semantically associated verbs to a string of visually and aurally presented nouns. This task involved both lexical processing and response selection. The semantic monitoring task required subjects to read a list of nouns and report the proportion of nouns belonging to a particular semantic category (e.g., dangerous animals). Two lists were presented: one with a small proportion of nouns belonging to the target category (i.e., 1/40), and a second with a larger proportion of nouns belonging to the target category (i.e., 20/40). This task required both semantic processing and association. Peterson and colleagues (1989) found increased activity in the cingulate gyrus (particularly its anterior portion) for tasks requiring a high level of attention and response selection. The activated region of the cingulate gyrus corresponded

to an area identified through lesion studies as being involved in spontaneous speech. The cingulate gyrus may thus be involved in spontaneous, cortically induced reflex movements (Carpenter & Sutin, 1983; Paxinos, 1990; Lem, this volume).

Although the limbic system is diffuse, it brings together principal pathways connecting thalamic nuclei with several other structures (Carpenter & Sutin, 1983), including (1) the BRF (involved in arousal), (2) the hippocampus (involved in memory), and (3) the amygdala (involved in affective evaluation of stimuli—Schumann, 1990, 1991) (Figure 1). Thus, through both direct and indirect connections, the NRT is in a position to modify critical linguistic processes carried out by the above-mentioned structures. Knowledge of the NRT's location and connections establishes its participation in information flow and suggests a possible role in learning. An examination of the structure of the NRT reveals its function, specifically how it participates in selective attention.

Structure

The NRT modulates communication to and from the cerebral cortex by synapsing (i.e., forming "communicative junctions") with thalamocortical and corticothalamic axons. Because the dendrites (i.e., the receptive branches) of NRT neurons run parallel to the boundaries of the NRT, all thalamocortical and corticothalamic axons must come into contact with these dendrites (Figure 3) (Scheibel & Scheibel, 1966; Jones, 1985). As these fibers pass through the NRT, they continually share information with the dendrites of NRT neurons. Constant communication between the thalamus and the cortex guarantees that NRT neurons receive continuously updated information.

The NRT's ability to monitor information flow is enhanced by filament clusters located at the end of each dendrite (Figure 3) (Scheibel & Scheibel, 1966; Jones, 1985). Just as leaves increase the surface area of a tree, and therefore increase its ability to absorb sunlight, filament clusters increase the dendrite's ability to absorb information (Jacobs & Schumann, 1992).

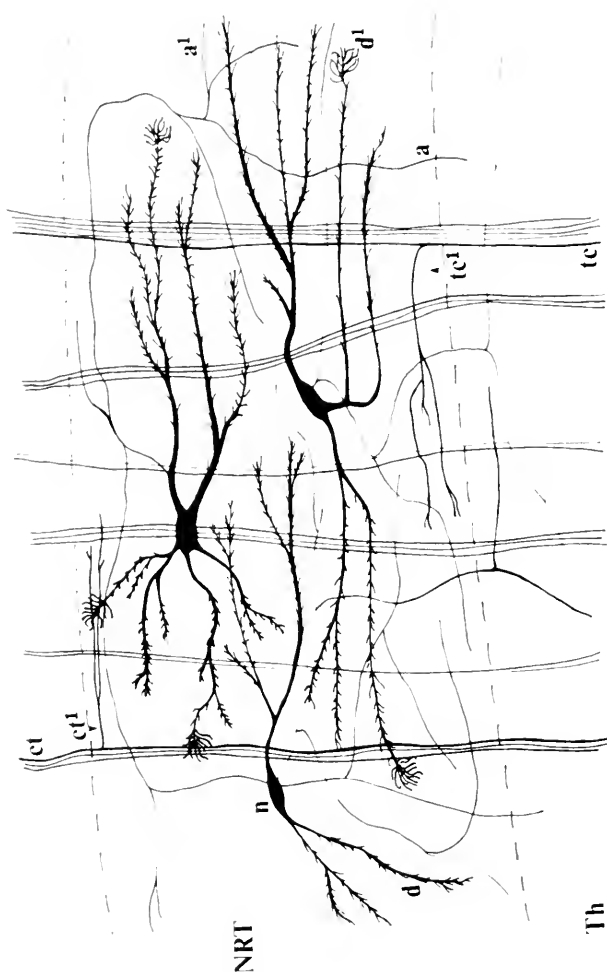


Figure 3. Representative illustration of the nucleus reticularis thalami's (NRT) extensive network of dendrites (d) as they run parallel to the NRT's boundaries. These dendrites end in filament clusters (d^1), which enhance the NRT's capacity to receive impulses from collaterals (tc^1 , ct^1) of traversing thalamocortical (tc) and corticothalamic (ct) fibers. Nucleus reticularis thalami (NRT) neurons (n) also emit axons (a), which contribute collaterals (a^1) to the NRT proper before descending toward underlying thalamic nuclei (Th). (Based on Golgi drawings of cat tissue in Scheibel & Scheibel, 1966.)

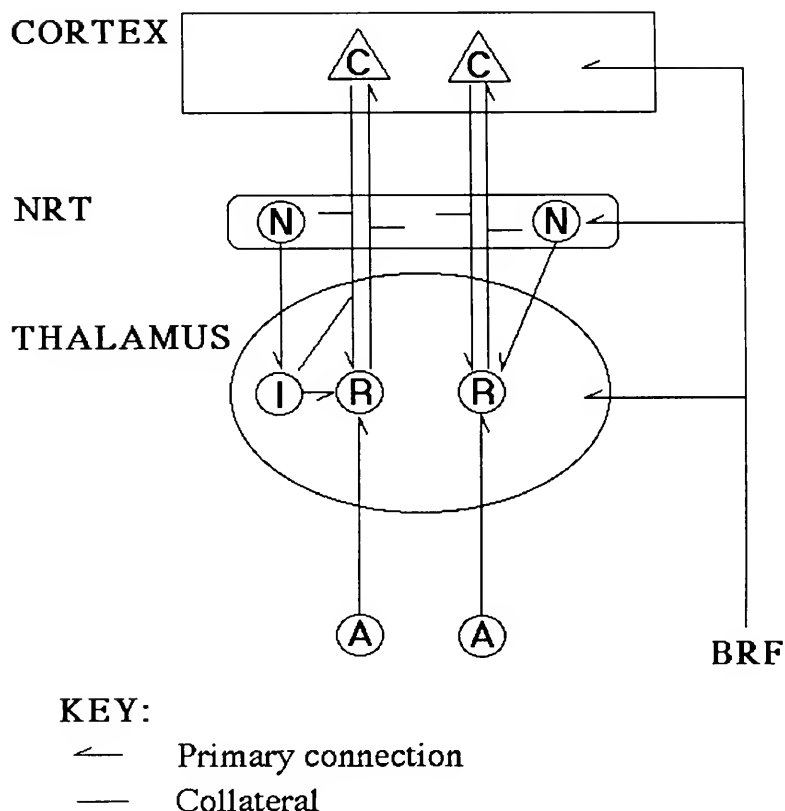


Figure 4. Highly schematized drawing illustrating the major components of the NRT's feedback circuit. Afferent (incoming) information (A) travels to thalamic relay cells (R) from several sources (e.g., the cerebellum and sensory receptors). These thalamic relay cells continually communicate with the cerebral cortex (C). Thalamocortical and corticothalamic communication, however, is differentially affected by thalamic interneurons (I) and NRT neurons (N), which function independently or in conjunction with each other. The brainstem reticular formation (BRF) contributes to this system via projections to the thalamus and NRT neurons en route to the cortex. (Synthesized from Skinner & Yingling, 1977; Scheibel, 1980; LaBerge, 1990.)

The NRT is not only a passive "eavesdropper." It can also intervene in communication between the thalamus and the cortex via

its axons. After emitting a few collaterals (= short extensions) that remain within the NRT itself, NRT axons project diffusely to the underlying thalamus (i.e., the dorsal thalamus) (Steriade et al., 1990). NRT axons contact two types of cells in the various thalamic nuclei: relay cells and interneurons. Relay cells are characteristically excitatory, that is, they promote information flow. Relay cells process a single sensory modality, project to specific regions of the cerebral cortex, and receive continually updated information from cortical regions to which they project (Kandel et al., 1991). In contrast, interneurons are primarily inhibitory. They do not project beyond the boundaries of the thalamus, but serve as an inhibitory interface between thalamic cells.

It has been suggested that NRT projections to relay cells and interneurons of other thalamic nuclei establish part of a feedback system which provides a mechanism for focusing attention (Scheibel & Scheibel, 1972; Scheibel, 1981). Other projections contributing to the NRT's feedback circuitry are the collaterals from traversing thalamocortical and corticothalamic axons, as well as projections ascending through the brainstem to the cortex. The primary components of the NRT's feedback system are thus: (1) the thalamic sensory nuclei, (2) the cortex and (3) the BRF (Hobson & Scheibel, 1980; Jones, 1985; LaBerge, 1990; Steriade et al., 1990). The major components of this feedback system continually communicate with each other regarding sensory input. The result of this continual communication is the transformation of selected input into intake. This feedback system, represented schematically in Figure 4, is discussed in greater detail below.

Physiology⁴

Enhancing the contrast of incoming information. The NRT modulates a topographically organized feedback system. Within this system, the NRT (1) monitors continuously updated communication between interconnected structures (e.g., thalamus and cortex) and (2) promotes the activity of selected neurons as they transmit sensory information to associated regions of the cortex. One of the main functions of NRT modulation is to enhance *contrast* among incoming sensory signals, a phenomenon crucial to CNS activity because neurons respond preferentially to contrast. In general, neurons prefer novel information and tend to cease responding (i.e., habituate) to repetitive and/or non-meaningful

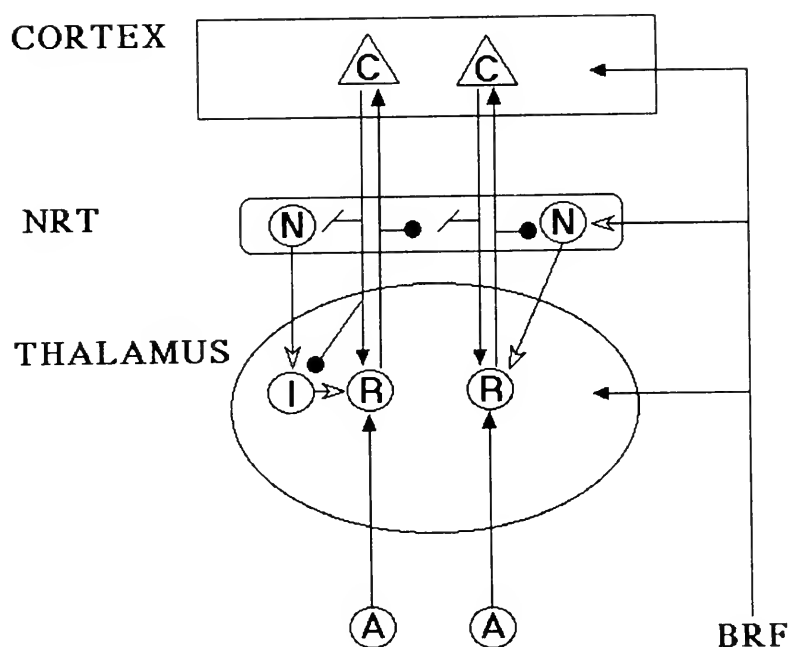
stimuli. Habituation helps explain, for example, how a person can forget eyeglasses on his/her forehead. It has also been suggested that because the CNS becomes accustomed to steady states of sensory impulses, pedagogical methods such as Audio-lingualism, which emphasize parrot-like repetition of chained phrases relatively devoid of meaning, have inherent neurobiological shortcomings (Jacobs & Schumann, 1992).

The NRT is active in selectively enhancing and simultaneously suppressing (inhibiting) information that flows through thalamocortical fibers. Ascending impulses from active thalamic neurons are thus enhanced as the NRT attenuates the expression of surrounding neurons, creating a greater contrast or signal-to-noise ratio (LaBerge, 1990). The NRT's inhibitory nature is evidenced by the fact that virtually all NRT neurons contain a chemical (the neurotransmitter gamma-aminobutyric acid, or GABA) that typically has an inhibitory effect.

NRT effects on behavioral states. Most research establishing the inhibitory nature of the NRT uses the electroencephalograph, an instrument that records the electrical activity of the brain (LaBerge, 1990; Steriade et al., 1990). This instrument correlates cell functions with electrical phenomena (= currents). Electrophysiologically, the NRT serves as a "pacemaker" of thalamic activity (Hobson & Scheibel, 1980; Steriade et al., 1990). Thalamic neurons have two distinct electrical discharge patterns, each of which is associated with a different behavioral state. The first is characterized by *synchronous* fluctuations, which are associated with drowsiness and deep sleep. This synchronous activity in the NRT seems to *prevent* sensory information traveling through thalamocortical fibers from being forwarded to the cortex for further processing (Steriade et al., 1990). The second type of current is characterized by *asynchronous* bursts. These are associated with brain-activated behavioral states, such as wakefulness, arousal and rapid eye movement (REM) sleep (Steriade et al., 1990). Asynchronous activity in the NRT enhances the transmission of impulses ascending from the thalamus to the cortex (Steriade et al., 1990), a key aspect of selective attention and learning. Because the NRT projects to virtually all thalamic nuclei, it appears to conduct the rhythmicity of the thalamus, thereby continuously modulating input to the cortex (Skinner & Yingling, 1977).

The NRT as a "gating" mechanism. Selective attention appears to result from the NRT's inhibition of thalamocortical impulses carrying irrelevant information. This selective inhibition implies that the NRT can somehow discriminate between relevant and irrelevant stimuli in a given context (Skinner & Yingling, 1977).⁵ As mentioned above, the NRT is part of an inhibitory feedback system which brings together information from the BRF, the cortex, and the thalamic sensory nuclei (Yingling & Skinner, 1977; Scheibel, 1987) (Figure 4). Within this system, the NRT serves as a "gating mechanism." If NRT "gates" are open, information flow to the cortex is promoted; if the "gates" are closed, information flow to the cortex is inhibited (Scheibel, 1987; Steriade et al., 1990). Both the BRF and the cortex (particularly the prefrontal region) affect the NRT's gating function.

Figure 5. Highly schematized drawing representing the physiology of the NRT's inhibitory feedback circuit. Brainstem reticular formation (BRF) projections excite thalamic relay cells (R) and inhibit NRT neurons (N). The BRF can suppress the inhibitory effect of NRT axons on thalamic relay cells, thereby opening the NRT "gate" and promoting thalamocortical information flow. The BRF can also suppress the inhibitory effect of NRT axons on thalamic interneurons (I), allowing thalamic interneurons to resume their suppressive control of thalamic relay cells. In this manner, the NRT "gate" is closed, restricting thalamocortical information flow. The cerebral cortex (C) (particularly the prefrontal region) exerts descending control over cells in the thalamus and the NRT, and has either an excitatory or inhibitory effect. The inhibitory effect of collaterals from corticothalamic fibers on NRT neurons is similar to that of BRF projections. The excitatory effect of corticothalamic collaterals increases the inhibitory effect of NRT axons on thalamic relay cells, closing the NRT "gate" and restricting thalamocortical information flow. The excitatory effect of corticothalamic collaterals also increases the inhibitory effect of NRT axons on thalamic interneurons, suppressing the inhibitory effect of these interneurons, thereby allowing thalamic relay cells to resume their communication with the cortex. The NRT "gate" is thus open, promoting thalamocortical information flow. (Synthesized from Scheibel & Scheibel, 1966; Jones, 1975; Skinner & Yingling, 1977; Yingling & Skinner, 1977; Scheibel, 1980; Scheibel, 1984; Jones, 1985; LaBerge, 1990; Steriade et al., 1990.)



KEY:

- ← Primary connection - excitatory
- ⇐ Primary connection - inhibitory
- Collateral - excitatory
- /— Collateral - excitatory or inhibitory

BRF influences on the gating mechanism. The BRF regulates attention of a more general, reflexive nature (Skinner & Yingling, 1977; Yingling & Skinner, 1977; Scheibel, 1980). Selective attention driven by the BRF helps explain, for example, how an individual directs his/her attention towards the source of a loud noise. As illustrated in Figure 5, axons ascending to the cortex from the BRF project to the thalamus, facilitating thalamocortical communication. All thalamic nuclei under the BRF's influence send sensory information to their associated areas of the cortex for further processing.

BRF projections to the NRT have an inhibitory effect. When NRT neurons are inhibited, their suppressive control of both thalamic relay cells and interneurons is removed. As *thalamic relay cells* are released from NRT suppression, thalamocortical information flow is promoted. The NRT "gate" is thus opened. As *thalamic interneurons* are released from NRT suppression, thalamocortical information flow is suppressed because the interneurons resume their inhibition of thalamic relay cells. The NRT "gate" is thus closed. The complex sequence of opened and closed gates appears to be responsible for the selective processing of sensory information by the cortex (Scheibel, 1980).

Cortical influences on the gating mechanism. Information flow is regulated not only from "below" by the BRF, but also from "above" by the cortex. This process is known as *descending control* and explains how the cerebral cortex can help select the information it receives from the environment. The cortex, in particular the projections from the prefrontal area to the midline nuclei of the thalamus (the intralaminar, nonspecific thalamic nuclei), tends to regulate more discriminate, voluntary types of attention (Skinner & Yingling, 1977; Scheibel, 1980). Selective attention driven by the prefrontal cortex helps explain, for example, how an individual is able to focus his/her attention on one speaker in a noisy room (i.e., the *cocktail party* phenomenon) and perhaps on specific aspects of linguistic input (Jacobs, 1988).

As for the circuitry itself, collaterals from prefrontal projections to the thalamus can have either a facilitatory or inhibitory effect on NRT neurons. Inhibition of NRT neurons by the cortex is similar to NRT inhibition by the BRF (discussed above). Facilitation of NRT neurons increases the NRT's inhibitory effect on active thalamic relay cells and interneurons. The NRT's direct connections with thalamic relay cells suppress the two-way communication between relay cells and the cortex. In this manner,

the NRT "gate" is closed and thalamocortical information is inhibited. However, the NRT is also able to promote thalamocortical information flow through its connections with thalamic interneurons. In this manner, the NRT "gate" is opened. As relay cells are released from the suppressive control of interneurons, thalamocortical information flow is promoted.

Whereas the BRF influences NRT control of more general, reflexive attention, the cortex plays more specifically on the NRT by influencing NRT control of discriminative, voluntary forms of attention.⁶ As such, cortical influences are particularly important for the selective attention necessary to attach meaning to sensory signals, including those of a linguistic nature (Jacobs, 1988).

CONCLUDING REMARKS: SPECULATIONS ON THE NRT'S RELEVANCE TO LANGUAGE ACQUISITION

Although a great deal is known about the neurobiology of the NRT, its role in language acquisition is largely speculative. The neurobiological factors presented above strongly suggest the NRT, in concert with other brain structures, plays a crucial role in selectively processing sensory input, including input relevant to language. The key assumption here is that information ascending through the NRT to the cerebral cortex constitutes *intake* (or at least potential *intake*), which is the metaphorical equivalent of integrated and retrievable neural representations. Such neural representations of the external milieu (including knowledge of language) provide the building blocks for continued knowledge (language) acquisition.

In early primary language acquisition, it is likely that the NRT functions in close association with the general arousal mechanisms of the young child. As discussed above, the NRT's role in selective attention constitutes a refinement of the phylogenetically older BRF's general arousal and alerting functions, which are particularly important for a developing brain that is continually exposed to and shaped by a pre- and post-natal environment rich in contextually supported novelty (Jacobs, 1988). The novel environment is essential because stimulus selection is often based on novelty or relevance, as determined by the learner's prior knowledge (i.e., "internal context") (Jacobs, 1991). Because the fetus and neonate are particularly responsive to the acoustic environment (Brazelton, 1986; Turkewitz, 1988; Fernald,

Taeschner, Dunn, Papousek, de Boysson-Bardies & Fukui, 1989; Fernald, 1990), and because the brainstem is functionally active at birth (Chugani, Phelps & Mazziotta, 1987), it seems likely that the NRT, under the influence of the BRF, can preferentially direct attention to those aspects of the environment important for language acquisition (e.g., rhythmicity, intonation, frequency variation, and the phonetic components of speech) (Morse, 1972; DeCasper & Fifer, 1980; DeCasper & Spence, 1986).

The prosodic modifications attracting the neonate's attention during this crucial period of brain development exhibit primarily a social-regulatory function (e.g., regulating arousal and attention; expressing communicative intentions of an affective nature such as approval, prohibition, comfort) (Stern, Spieker & MacKain, 1982; Stern, Spieker, Barnett & MacKain, 1983; Fernald, 1991). Towards the end of the first year, however, prosody serves more of a linguistic or analytic function (e.g., focusing attention on objects, enhancing the perceptual salience of individual words, marking linguistic units) (Stern et al., 1983). This may help the child learn new lexical items, parse the speech stream, and identify syntactic units (Gleitman & Wanner, 1982; Peters, 1983; Morgan, 1986; Morgan, Meier & Newport, 1987; Fernald, 1991), thereby laying the foundation for further language acquisition.

Although the BRF maintains its ability to open the NRT "gate" for the lifetime of the organism, the cerebral cortex gradually assumes greater influence over the NRT as the brain matures. Cortical descending control over the NRT would thus assume increasing responsibility in later stages of first language acquisition and in second language acquisition. This is especially true for the descending influence of the prefrontal area, which does not achieve functional maturity until the second decade of life (Chugani et al., 1987). In regulating discrete aspects of attention, the prefrontal cortex provides an individual with a certain degree of control over the sensory (including linguistic) information passing through the NRT gate. After contextualized linguistic input (i.e., external context) is directed to the appropriate cortical area, it may be integrated with extant neural structures (i.e., internal context). In this manner, cortical influences are particularly important for the selective attention necessary to attach meaning to sensory signals, including those of a linguistic nature (Jacobs, 1988).

In conclusion, several neural structures work in concert to manage the overwhelming array of environmental input available to the language learner by selecting and enhancing relevant information to augment previously stored knowledge. These brain regions

appear to be coordinated by the NRT which, on the basis of its structure and location, is ideally suited for the task of monitoring information as it flows to and from the cerebral cortex. Although the claims of the present paper derive primarily from work in nonhuman animals, the fundamental neural principles presented here extend to humans without difficulty (Jacobs & Schumann, 1992). The NRT's posited role in language acquisition is at present neither directly observable nor testable. Nevertheless, the present discussion demonstrates that neurobiology provides plausible mechanisms (rather than metaphors) for understanding how learners internalize linguistic patterns available in input.

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Address all correspondence to Edynn Sato, Department of Applied Linguistics, 3300 Rolfe Hall, University of California, Los Angeles, CA 90024; Email: IZZYCJ3@MVS.OAC.UCLA.EDU.

NOTES

¹ The brainstem reticular formation (BRF) is one of the oldest structures in the brain and is essential for the organism's survival. Neural pathways ascending to the cortex contribute collaterals to the BRF, providing it with continually updated information. Some of these collaterals maintain their sensory specific modality and serve as sensory relay systems. Other collaterals lose their sensory specific identity, but acquire the capability to activate electrocortical currents characteristic of the brain's attentive or aroused state.

² *Arrest of speaking* refers to the subject's inability to speak at all during stimulation. *Anomia* refers to the inability to name objects during stimulation. *Perseverance* refers to the repetition of the object's correct name or first letter of the object's name during stimulation. *Repetition* refers to the repeated utterance of a wrong word during stimulation.

³ Although the amygdala is phylogenetically associated with the basal ganglia, it is functionally associated with the limbic system (Kandel et al., 1991).

⁴ For the sake of clarity, this section oversimplifies the physiological story considerably. A more detailed discussion of the physiology can be found elsewhere (e.g., Skinner & Yingling, 1977; Yingling & Skinner, 1977; Scheibel, 1984; Steriade et al., 1990).

⁵ It is extremely difficult to ascertain precisely what input is "relevant" to the learner because relevance is determined by the complex interplay of many factors, including (1) the internal context of the learner, (2) the external or situational context, and (3) the period of development during which the individual is exposed to a given input.

⁶ *Descending control* can be clarified by example. When an individual watches television, the BRF's general, reflexive influence is apparent when attention is captured by a sudden change of scene, unexpected action, or fluctuation in volume. The descending control of the cerebral cortex is manifested when an individual manages to maintain attention, despite drowsiness, in order to comprehend key elements of the program.

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Edynn Sato is a Ph.D. Candidate in Educational Psychology. Her research attempts to integrate various disciplines (i.e., Educational Psychology, Applied Linguistics, and Neuroscience) to understand learners' abilities and limitations. In particular, her interests are: (1) the impact of the environment on brain development and (2) the role of selective attention in learning.

Bob Jacobs recently completed an interdisciplinary dissertation (entitled: A quantitative dendritic analysis of Wernicke's area) in applied linguistics with a focus on cognitive neuroscience. Currently, he is a postdoctoral fellow in the UCLA Division of Nuclear Medicine and is investigating the metabolic development of the brain with positron emission tomography (PET).

Towards a Model of Language Attrition: Neurobiological and Psychological Contributions

Asako Yoshitomi
University of California, Los Angeles

Research in L2 attrition is a relatively new enterprise which is in need of a comprehensive theory/model. This paper presents a tentative cognitive-psychological model of language attrition, which draws on information from studies in L2 attrition, neurobiology, and psychology. This is to demonstrate that a model based on consideration of the brain has the potential of providing a plausible account of the process of language attrition, as well as the process of language acquisition.

INTRODUCTION

Language attrition refers to "the loss of any language or any portion of language by an individual or a speech community" (Lambert & Freed, 1982, p. 1). Four types of language attrition are generally recognized: first language (L1) loss, second or foreign language (L2/FL) loss¹, death of an entire language, and language deterioration in neurologically impaired patients or the elderly. The focus of the present paper will be on L2 attrition.

Although L2 attrition has recently gained attention, the number of studies is still limited, and there is a need for a theory or model of L2 attrition. The few theories or models now available offer only descriptions or abstract characterizations of linguistic behavior (e.g., "generalization," "simplification," etc.). These, however, are merely useful metaphors which, by themselves, do not provide an account of why such behaviors take place (Churchland, 1986; Schumann, 1990a). A model of the mind/brain should incorporate neurobiological reality in order to provide a more plausible explanation of the process of language acquisition and

attrition (Jacobs & Schumann, 1992). Thus, an attempt is made here to demonstrate that neurobiology has significant bearing on the formation of a model of language attrition.

The present paper (1) summarizes key findings in L2 attrition research², (2) examines the neurobiological basis for language attrition, and (3) provides a tentative model of language attrition. The summary illustrates what must be accounted for in a model of language attrition. Neurobiology provides a means to account for language attrition. The tentative model is a result of integrating findings from studies in L2 attrition, neurobiology, and psychology.

SECOND LANGUAGE ATTRITION RESEARCH

Summary of findings in L2 attrition studies

In sum, a model/theory of language attrition must be able to account for, as least be compatible with, the following characteristics observed in language attrition data:

- (1) loss in reverse order of acquisition;
- (2) inverse relationship between loss and language proficiency;
- (3) critical threshold of knowledge beyond which loss is less likely;
- (4) residual learning in the beginning of the incubation period;
- (5) initial plateau before attrition sets in;
- (6) permastore content and the retention of frequent and/or pragmatically laden expressions, regardless of lack of input and use;
- (7) attrition as a gradual process from less accessibility to complete loss;
- (8) critical period of language attrition around the age of 8 or 9;
- (9) the amount of L2 use rather than length of exposure as determining language proficiency and degree/rate of loss;
- (10) affect as an indirect determinant of language use and attrition.

The following sections provide some elaborations of these characteristics.

The Reverse Order Hypothesis: Last Learned, First Forgotten

The process of forgetting a language is often believed to be the undoing of the learning process. The notion has been interpreted to refer to two related but different characteristics of language loss: the "reverse order hypothesis" and the "inverse relation hypothesis." The reverse order hypothesis, which comes from the notion of "regression" in aphasia. (Jacobson, 1962), states that attrition is the mirror image of acquisition, that is, the last thing learned is the first to be forgotten. The hypothesis may refer to three different linguistic levels (De Bot & Weltens, 1991): (i) within skills--within phonology, morphology, syntax, lexicon, etc. (i.e., intra-skills level); (ii) within languages--in acquisition, perception precedes production, and spoken language precedes written language; in language loss, the sequence is reversed (i.e., intra-linguistic level); and (iii) between languages--with respect to the order of acquisition and loss of languages in multilinguals (i.e., inter-linguistic level).

The reverse order hypothesis at the intra-skills level has been tested and supported cross-linguistically (Cohen, 1975; Berman & Olshtain, 1983, Olshtain, 1986; Hansen, 1980, cited in Weltens, 1987; Moorcroft & Gardner, 1987; Jordens, De Bot & Trapman, 1989; and Olshtain, 1989). These studies investigated the use of specific grammatical structures by L2 learners and generally found that forms learned latest were lost first. The generalizability of reverse order at the intra-level skills level is limited, however, because the hypothesis has been tested only on a limited number of specific syntactic structures.

The reverse order hypothesis at the intra-linguistic level has been tested as well (Kennedy, 1932; Geoghegan, 1950; Scherer, 1957; Smythe, Jutras, Bramwell & Gardner, 1973; Cohen, 1974; Bahrick, 1984a, 1984b; Moorcroft & Gardner, 1987; Weltens, 1987; Van Els & Weltens, 1989; Weltens & Cohen, 1989; Weltens, De Bot & Schils, 1989; Yoshida, 1989; Seya, 1990; Yoshida & Arai, 1990). The majority of these studies assessed language skills before and after a three month summer vacation and analyzed the types and amount of skills lost as a result of the interval. Results are mixed, perhaps because relatively little loss takes place during such a short interval. There are indications of "residual learning" (Cohen, 1975; Scherer, 1957; Weltens et al., 1989), a phenomenon whereby incorrect patterns become "unlearned" (e.g., hypercorrection of a certain form disappears) after L2 use is discontinued. Nevertheless, the reverse order hypothesis at the intra-linguistic level appears to be

generally supported: phonological skills are retained better than lexical and grammatical skills, receptive (i.e., listening, reading) skills better than productive (i.e., speaking, writing) skills, metalinguistic skills better than linguistic skills, listening skills better than reading skills, and semantics/vocabulary better than syntax/grammar. The reverse order hypothesis at the inter-linguistic level, compared with the intra-skills level and the intra-linguistic level, remains largely unexplored.

The Inverse Relation Hypothesis: Better Learned, Better Retained

The inverse relation hypothesis postulates that there is an inverse relationship between proficiency level prior to the onset of attrition and the rate and/or the amount of loss. In other words, what is learned best is least forgotten, and those who have learned better, or become more proficient, are less vulnerable to loss. The hypothesis has been supported by several studies (Godsall-Myers, 1981; Bahrick, 1984a; 1984b; Moorcroft & Gardner, 1987).

The influence of L2 proficiency on the order of loss has been observed in studies which found that beginning students lose more grammar than vocabulary, while advanced students lose more vocabulary than grammar (Moorcroft & Gardner, 1987; Weltens, 1987; Van Els & Weltens, 1989; Weltens & Cohen, 1989; Weltens et al., 1989). Moorcroft and Gardner (1987) attribute this finding to the degree of stability of L2 knowledge. They argue that less proficient learners have a relatively unstable knowledge of grammar and, therefore, are more likely to lose recently learned grammatical structures than vocabulary. In comparison, more proficient learners have a relatively stable knowledge of grammar, which is learned first, and a larger amount of lexical knowledge. They are, thus, more apt to lose vocabulary. Observations in L1 loss support such claims, since the lexicon is affected in L1 loss more so than grammar. Presumably, native speakers have a complete mastery of L1 grammar.

The level of L2 stability has been claimed to affect the degree of attrition as well (Olshtain, 1986; De Bot & Clyne, 1989). Neisser (1984) proposes that there is a "critical threshold" of language proficiency level beyond which language skills become less vulnerable to attrition. What Pan and Berko-Gleason (1986) call the "critical mass of language that, once acquired, makes loss unlikely" (p. 204) seems to refer to an identical notion. The notion is in line with studies which report an "initial plateau" or "a period of

a few years during which skills are relatively unaffected before attrition actually sets in" (Weltens & Cohen, 1989, p. 130), especially in the case of high proficiency L2 learners (Weltens & Van Els, 1986; Weltens, 1989; Snow, Padilla, & Campbell, 1984 and Schumans, Van Els, & Weltens, 1985, both cited in Weltens & Cohen, 1989). In other words, a learner who has reached the critical threshold of L2 proficiency is more likely to exhibit some resistance to attrition, especially in the early stages of disuse. It is important to note that the level of proficiency is not necessarily the consequence of length of exposure/training (Kennedy, 1932; Flaughter & Spencer, 1967).

Not all of the studies mentioned above explicitly test the reverse order hypothesis or the inverse relation hypothesis, and scarcely any study has tested both hypotheses together. Nevertheless, the literature taken together seems to imply that the two hypotheses capture the main linguistic characteristics of language attrition. It may be that the two hypotheses refer to separate processes taking place in language attrition, since "what is best learned, whether early or late in the acquisitional history" may "be last lost" (Berko-Gleason, 1980, p. 8 cited in Freed, 1982). In the present study, however, the two processes are viewed to be outcomes of identical biological mechanisms that underlie language acquisition and attrition.

The Effect of L2 Use on Attrition and the Existence of Permastore L2 Knowledge

Although degree of attrition is generally a function of the length of L2 disuse, there are certain linguistic elements that survive loss regardless of lack of practice (Berman & Olshtain, 1983; Bahrack, 1984a; 1984b; Moorcroft & Gardner, 1987; Weltens 1987; Lambert, 1989; Nakazawa, 1989a, Yoshida, 1989; Nakazawa & Yoshitomi, 1990; Seya, 1990; Yoshida & Arai, 1990; De Bot, Gommans, & Rossing, 1991). These elements include listening comprehension, phonology, and metalinguistic skills in general as well as very frequent and/or pragmatic-laden items such as closed class vocabulary, idioms/fixed expressions, and interjections and fillers (e.g., um).

Bahrack (1984a, 1984b) found that while a large portion of Spanish knowledge is lost within a few years after the termination of training, the remainder is immune to further losses for as long as 25 years. Much of that content survives 50 years or more. Bahrack calls this "portion of knowledge with a life span in excess of 25

years" "the permastore content" (1984a, p. 111), and concludes that (1) a large amount of information can survive in the permastore with minimum rehearsals during the interval, (2) the amount of content in permastore is a function of the level of training (i.e., length of training, final course level and grade), and (3) a large proportion of semantic knowledge (especially receptive vocabulary) is retained in permastore-content.

Language Attrition, Aphasia, Dementia, and the Speech of the Elderly

Although a parallel between language attrition and aphasia claimed by Jakobson (1962) has been challenged (Caramazza & Zurif, 1978; De Bot & Weltens, 1991), impressive similarities between language attrition and dementia, and between language attrition and the speech of the elderly have been suggested (Obler, 1982; Obler & Albert, 1989). Linguistic elements which are particularly robust include items, such as function words, certain overlearned sequences/automatic speech, as well as emotion-laden items, proverbs/idioms, and metalinguistic knowledge.³

Attrition as Complete Loss Versus Decreased Accessibility

Aside from the retention of certain permastore-content, and following the initial resistance to attrition (i.e., initial plateau, residual learning) in the case of proficient learners, the attrition process exhibits a normal forgetting curve, involving a large loss followed by a more gradual loss (Godsall-Myers, 1981; Yoshida, 1989). Attrition may not necessarily refer to complete loss of skills/items but to difficulty in retrieving them. Evidence of retrieval difficulty is observed in strategies adopted by people suffering language loss, such as "progressive retrieval" of lexical items, where people start with an inappropriate choice of a word and eventually arrive at the correct one (Sharwood-Smith, 1983; Cohen, 1986, 1989; Olshtain, 1989), and circumlocution as a means of avoiding words which have become less accessible (Olshtain & Barzilay, 1991; Turian & Altenberg, 1991). Better performance on recognition tasks than on recall tasks (Bahrick, 1984a, 1984b) also implies that items have not been completely lost from memory.

Critical Period of Language Attrition

Age and cognitive development are very likely to have significant effects on language attrition. The limited number of studies to appear so far imply that children older than 9 years of age suffer less language loss, especially if they have reached a certain stability in L2 knowledge (Berman & Olshtain, 1983; Olshtain, 1986, 1989; Cohen, 1989, 1989; Yoshida, 1989; Yoshida & Arai, 1990).

Berman and Olshtain (1983), Olshtain (1986), and Olshtain (1989) are longitudinal studies which examined the attrition of English as an L2 of Hebrew-speaking returnee children, aged 5 to 14. The younger children, aged 5 to 8 years old, exhibited a reversal process of acquisition in their uses of irregular noun plural forms and verb past forms, while the older children did not (Olshtain, 1989). Olshtain (1986) suggests that the older children's knowledge of irregular forms had reached a level of stability which reduced the possibility of losing them despite the lack of positive feedback. Speaking and writing skills were also lost most significantly with the younger subjects (Berman & Olshtain, 1983).

Studies by Yoshida (1989) and Yoshida and Arai (1990), which investigated the attrition of English as an L2 of Japanese returnee children aged 6 to 15, also imply that age might influence the degree and/or rate of attrition. Although there was a tendency for L2 speaking skills to decline as a function of length of non-use, children over 8 years of age generally outperformed the younger children in terms of vocabulary use, utterance number, length, and complexity, regardless of the length of interval. Better retention of productive vocabulary in oral language by a 13-year-old is reported in Cohen (1989) as well. The younger child of age 9 exhibited greater loss both in the types and tokens of the vocabulary produced during a storytelling task.

Studies in psycholinguistics and neuroscience suggest that there are maturational constraints on language acquisition (Oyama, 1976, 1978; Johnson & Newport, 1989; Long, 1990). From an extensive review of the literature, Long (1990) concludes that there seem to be multiple sensitive periods to language acquisition. The sensitive period for acquisition of native-like phonology ends at about 5 years of age, while the sensitive period for acquisition of native-like syntactic knowledge ends at about 15 years of age. Different rates and degrees of loss found across linguistic levels (i.e., reverse order hypothesis at the intra-linguistic level) may be a consequence of such multiple sensitive periods.

Research on children raised in the wild, deaf children and aphasics also support the notion of maturational constraints. Curtiss (1981), in her study of the literature on isolated children, observed that children whose approximate age at discovery was over 8-10 years, developed little or no language (i.e., syntax and function word vocabulary). studies on the acquisition of American Sign Language suggest that there is a critical period for acquiring the morphological system of sign language, which may end as early as 7 years of age (Newport & Meier, 1985; Newport & Supalla, 1990). Moreover, Curtiss (personal communication) suggests that the critical period for language acquisition may be earlier than puberty, around 8 to 10 years of age. Taken together, studies cited in this section indicate the possibility of a common critical period for language (especially productive syntactic skills), generally occurring by the end of the first decade of life.

Affect and L2 attrition

Gardner and his colleagues maintain that the use of L2 during the incubation period (i.e., the period between the termination of language training and the time when retention is assessed) is crucial for retention, and that motivation plays a mediating role to enhance both the initial language acquisition and the use of L2 during the incubation period (Gardner, 1982; 1985; Gardner, Lalonde, Moorcroft & Evers, 1985; Gardner, Lalonde & MacPherson, 1987; and Gardner & Lysynchuk, 1990). Other studies also stress the effect of language use (Edwards, 1976; 1977) and motivation (Nakazawa, 1989) on the degree of L2 loss. Social-psychological variables, which are crucial to the acculturation model in SLA (Schumann, 1978), are argued to be some of the main determinants of language loss as well (Olshtain, 1989; Olshtain & Barzilay, 1991).

It is interesting to note that items with great pragmatic load (i.e., "the extent to which the feature normally convey[s] extra-linguistic information such as affect or important status relationships") (Lambert, 1989, p. 8), including idiomatic expressions and social fillers, are less likely to be lost once they are learned (Berman & Olshtain, 1983; Lambert, 1989; Yoshida, 1990; De Bot & Weltens, 1991). Schatz (1989) proposes that such items signal the L2 learner's assimilation to the target culture. They may also be regarded as expressions that help the learners maintain real-life, social-communicative interaction.

NEUROBIOLOGICAL SUPPORT OF LANGUAGE ATTRITION PHENOMENA

Neural Plasticity as the Mechanism of Learning and Forgetting

The neurobiological basis of learning and memory is claimed to be a consequence of neural plasticity, the adaptive capacity characteristic of biological organisms (Squire, 1985). An organism "can modify its nervous system" and "later behave differently as a consequence of these modifications" (p. 295).

It has long been known that animals raised in enriched, complex environments perform better on various behavioral tasks than those raised in non-enriched, simple environments. Such differences in behavioral performance seem to result from neurobiological alterations (e.g., changes in gross morphology, brain weight, cortical histology, neurophysiology, neurochemistry, and dendritic branching) induced by environmental factors (Diamond, 1988; Jacobs, 1991; Jacobs & Schumann, 1992; Jacobs & Scheibel, *In Press*).

Studies on the effect of an enriched environment are gradually being extended to humans. Dendritic branching analyses, which are claimed to reveal the cortical consequences of formal learning (Holloway, 1966), have indicated that the quantity of dendrites in the gray substance of the human brain and spinal cord (i.e., dendritic neuropil) is a possible function of education level and/or predominant lifetime experiences such as occupation (Scheibel, Conrad, Perdue, Tomiyasu & Wechsler, 1990; Jacobs, 1991; Jacobs, Schall & Scheibel, *In Press*). Idiosyncrasies found in cortical topographical representations are largely dependent on anatomical changes reflecting individual experience (Merzenich, Recanzone, Jenkins & Grajski, 1990).

Recent advances indicate that information is contained in connections between neurons (i.e., nerve cells), and that use-dependent anatomical change in such connections is a possible substrate for enduring increases in synaptic connectivity essential for memory storage (Squire, 1985). Neuronal connectivity involves dynamic processes such as cooperation, competition, and reorganization among neural elements. The formation and modification of connectivity occur throughout life. The wiring of the brain is only roughly aligned prenatally, during which the target of synaptic connections is defined genetically. The process of fine

tuning continues well after birth, but becomes dependent on the specific interactions between the organism and its environment (Kandel & Jessell, 1991). Increases in synaptic strength in the mature nervous system are typically accompanied by decreases in the strength of competing connections (e.g., competitive changes in axons occurring in the representation of the hand in adult sensorimotor cortex due to experience-based variables) (Purves & Lichtman, 1980; Wiesel, 1982; Jenkins & Merzenich, 1984; Squire, 1986). There are biological constraints, however, which limit the effects of environmental factors. Thus the process is both experience-based, genetic and epigenetic (Jacobs, 1988; Kupfermann, 1991a).

Memory Consolidation and Different Sites of Memory

Reorganization of connections that result from neuronal plasticity involves time. The idea that changes in memory storage occur across time was proposed by Burnham (1903), and is commonly referred to as "memory consolidation" (Squire, 1985). Squire (1985) proposes that there may be two subtypes of long-term memory: "intermediate memory," which is relatively sensitive to disruption, and a relatively permanent memory. According to Squire (1985), intermediate memory may be stored in the lateral part of the brain close to the midline (i.e., medial temporal lobe), whereas permanent memory may be memory transformed into the cortex on the external surface of the brain (i.e., neocortex).

Recent studies in neurobiology indicate that memory of stimuli is stored as changes in the same neural systems which participate in the stimuli's perception, analysis, and processing (Squire, 1986). In other words, the processing site of certain information becomes the memory storage site of that information, at least temporarily. This claim is based on data from patients with brain lesions. Lesions resulting in the loss of previously acquired information also impair the ability to re-acquire the same information. In complex processing, the respective information is assembled further by other higher-order systems (e.g., associative areas), resulting in the participation of a large amount of tissue without any redundancy or reduplication of function across levels. The distribution of memory storage sites will depend on the nature (e.g., complexity) of the information to be learned (Squire, 1985).

For example, in visual perception and memory, information about form is conveyed through different visual pathways from those that convey information about color. The cells in different

visual pathways show different selectivities and respond only to certain visual stimulus parameters, such as shape, form, size, and direction of movement (Kandel, 1991). Information about particular features of the stimulus converges in a higher-level visual processing region of the cortex (i.e., the inferior temporal cortex) that is thought to integrate such individual information into one representation (Squire, 1985). Thus, the storage of temporary information may occur in each cortical processing system, which is later associated at a different cortical region responsible for higher-level (e.g., cognitive) functions. It is now believed that such parallel processing and modular organization is present in all sensory cortices (Mason & Kandel, 1991). Memory, therefore, "is localized in the sense that particular brain systems represent specific aspects of each event, and it is distributed in the sense that many neural systems participate in representing a whole event" (Squire, 1986, p. 1613).

After immediate or short-term storage is accomplished at respective processing sites, changes in synaptic efficacy (i.e., consolidation) take place to form long-term memory. The transformation of working memory into long-term memory occurs at the higher stations of modality-specific and polymodal sensory systems, and subsequently at the medial temporal and diencephalic regions of the brain (i.e., areas located between the cerebral hemispheres and the mid-brain), which assemble the temporary information from neurons of respective memory storage sites located elsewhere in the brain (Squire, 1985). The memory system in the medial temporal lobe consists of the hippocampus and its adjacent, anatomically related cortices, which together play an essential role at the time of learning in establishing long-term memory, by binding the distributed sites of memory storage and maintaining the coherence of the whole representation. Knowledge, after reorganization and consolidation, eventually becomes stored in the neocortex, which has the effect of freeing the medial temporal lobe system for further learning or acquisition of new information (Squire & Zola-Morgan, 1991).

In amnesia, premorbid memory is considered vulnerable unless it has been consolidated and has become independent of the medial temporal region (Squire, 1985). Likewise, language knowledge that has not been integrated through competition and consolidation into permanent memory, is presumably more likely to erode in language loss.

Neural Plasticity and Consolidation as Neurobiological Support of the Reverse Order Hypothesis

Taken together, neural plasticity and consolidation of connections seem to provide a plausible explanation for the linguistic characteristics observed in language attrition. The reverse order hypothesis and the inverse relation hypothesis are possible outcomes of the same biological characteristic, neural plasticity, that governs changes in linguistic knowledge. Input frequency, an environmental factor, modifies the linguistic knowledge, which is presumably contained in the dynamic connections of neurons. Linguistic input is processed in parallel and in a modular manner in various sensory cortices, assembled in the medial temporal lobe, and eventually stored in the neocortex as consolidation takes place. Items which are frequent in the input and learned during the earlier stages of acquisition are more likely to have been consolidated and transferred to the neocortex. Infrequent and/or later acquired items, on the other hand, are presumably located in connections in the medial temporal lobe, which are more vulnerable to loss. In essence, information/knowledge is more susceptible to attrition in the order in which it is stored in working memory (i.e., modality-specific processing sites), intermediate memory (i.e., medial temporal region) and finally, permanent memory (i.e., neocortex).

Decreased Accessibility as a Consequence of the Gradual Weakening of Neural Networks

When attrition occurs, there may be an actual loss of some of the neural connections that originally represented acquired information. This view is supported by data on retrograde amnesia (i.e., difficulty in retrieving memories formed before the onset of amnesia, as opposed to anterograde amnesia, which involves difficulty in forming new memories). Many retrograde amnesics have access to their remote, premorbid memory but not to memories of things experienced some weeks or months before the injury. In addition, certain portions of retrograde amnesia are irreversible (Squire, 1985). If we assume that forgetting in amnesia and normal forgetting share an identical biological mechanism, the same rule could be applied to language attrition.

Language attrition, however, is a gradual and global process, unlike amnesia or other abnormalities induced by brain lesions in which immediate and specific deficits of parts of the language system follow. Consequently, people who are in the

process of losing their L1/L2 may initially suffer from a difficulty in retrieving information represented in weakening connections before the information is completely lost. "Relearning" of a language, documented in L1 attrition research (Berman, 1979) and ESL research (Celce-Murcia, 1979, cited in Hatch, 1983) may be the result of a "re-strengthening" of connections which were not completely lost during incubation. "Progressive retrieval" of lexical items observed in language attrition may be instances of weakening connections as well.

Attrition of Declarative versus Procedural Knowledge

It should be noted that the medial temporal region seems responsible only for memory of declarative knowledge. According to Squire (1986), declarative knowledge "is explicit and accessible to conscious awareness," and contrasts with procedural knowledge which is implicit, and "accessible only through performance, by engaging in the skills or operations in which the knowledge is embedded" (1986, p. 1614). Examples of declarative knowledge include facts, episodes, and lists, which can be declared. Procedural knowledge, on the other hand, includes simple forms of associative learning such as classical conditioning and habit. Studies on amnesia have shown that global amnesic patients who have lesions in the medial temporal region are impaired in retrieving long-term declarative knowledge and also exhibit problems in acquiring new knowledge. The amnesic patients' short-term memory and their memory for the very remote past, presumably permanent memory, are spared. Thus, the declarative knowledge lost in amnesia might be more specifically considered as intermediate memory. Such patients also maintain procedural memory, suggesting that procedural memory is a function of different regions of the brain, presumably the striatum, a complex of structures in the forebrain (Squire, 1986) and in the cerebellum (see Robbins, this volume).

If declarative knowledge refers to the ability to explicitly state linguistic rules, naturalistic acquirers of language would have little or not declarative linguistic knowledge. For them, linguistic knowledge, except for semantic knowledge perhaps, would be procedural knowledge. Although procedural knowledge could be represented declaratively as well, the two types of knowledge are stored in separate sites in the brain.

It is plausible to think, however, that procedural knowledge is acquired through stages similar to consolidation of declarative

knowledge. Such stages may involve increasing refinement of skills (Robbins, this volume) and thus, show similar attrition patterns in the reverse order of acquisition, with later stages "undone" first. The mechanism underlying declarative and procedural acquisition and attrition are possibly identical, namely, through modification of neuronal connections, but the location of alteration in the brain may be different in the two types of knowledge. At present, however, neurobiological studies on non-declarative knowledge are too scarce to assess the tenability of such argument.

Neurobiological Support of the Inverse Relation Hypothesis: Efficient Processing and Language Proficiency

Well-acquired items are presumably represented in connections in the medial temporal lobe and the neocortex. Hence, higher proficiency may mean a larger number of consolidated connections in long-term storage. Alternatively, higher proficiency may refer to more efficient connections. In fact, there are studies which show that people with high scores on intelligence tests require less brain energy than people with lower scores. Using positron emission tomography (PET) scans, Haier et al. (1988) measured the intensity of brain activity by recording the amount of an injected substance (a radioactively tagged glucose compound) absorbed by brain cells while subjects engaged in cognitive tasks. Novel tasks increased the amount of energy consumption, but with accumulated practice, brain metabolism decreased significantly. Furthermore, the brain metabolism of proficient task performers was found to be the least active. This finding implies that highly proficient L2 learners may be energy-efficient as well.

Interestingly, Haier and his colleagues noted that a few areas of the brain, including the hippocampus, were activated more after practice. This finding reconfirms the role of the hippocampus as one related to memory and learning. Furthermore, it suggests that more proficient learners are able to utilize information carried in the neuronal networks in long-term storage, and hence, are able to minimize the activation of networks in the initial processing areas in order to accomplish the task.

The brain analyzes new stimuli by comparing it with earlier acquired information and stores the new information in accordance with its similarities and differences to previous memories of the same type. The analysis consists of pattern detection and categorization, which is an important feature of consolidation

(Guyton, 1987; Jacobs, 1991). It follows from this that the richer "internal context" (i.e., prior knowledge) (Jacobs, 1988) one has, the more efficient the interaction with new stimuli will be. Greater efficiency implies the ability to neglect irrelevant information and thus, expend less brain energy.

In sum, proficient L2 learners may have a rich connection of networks in long-term memory which enables energy-efficient processing when acquiring new L2 knowledge. The neuronal connectivity in long-term memory is better developed and more extensive, thus, less immune to loss. In the same vein, the critical threshold of L2 knowledge may correspond to a certain amount and strength of storage in long-term memory which enable acquisition to be more energy conserving.

Neurobiological Support of Residual Learning, Initial Plateau, and Permastore

Since consolidation of memory takes time, language skills may be performed better after a certain lapse of time. For this reason, residual learning may be observed even when language use is discontinued. However, once new information has been reorganized, lack of input will result in the weakening of connectivity. The attrition curve, hence, exhibits an "initial plateau," or resistance to loss, followed by a more rapid and then gradual loss as language disuse continues. At least some portion of the information which has successfully entered permanent memory can be retained in spite of minimal use. Thus, the existence of "permastore" seems possible. Other information can still be retained if language is used, or the information is retrieved frequently enough, to maintain the strength of the connections. Otherwise, lack of input will result in the regression of morphological alterations in connectivity representing linguistic knowledge. Such regression has been observed with animals raised in an enriched environment and then put in an impoverished environment (Diamond, 1988).

Neurobiological Support of the Critical Period of Language Attrition

It has been observed that different regions of the brain have different critical periods of development (Kandel & Jessell, 1991). For example, the development of form perception and the binocular vision necessary for depth perception proceed in stages after birth,

each stage being irreversible. Appropriate sensory experiences are essential for normal developmental processes to occur. Hence, deprivation of appropriate stimulus input during the postnatal period when developmental decisions are being made seems to have the most severe consequences on the maturation of the nervous system in question. Although it has been difficult in the past to relate the development of behavior to the development of the nervous system, studies on the maturation of neurons in the visual cortex have come to provide an important bridge between behavior and the nervous system (Kandel & Jessell, 1991). Discrete stages in the formation of other nervous systems including those related directly to various linguistic skills could ultimately become clearer as well.

The dynamic changes of human dendritic systems triggered by environmental factors have been mentioned above. Dendritic change has also been observed to be age related. Jacobs and Scheibel (In Press) report age related decreases in the length of dendrites emerging from the base of the cell body (i.e., basilar dendrites) and dendritic laterality, loss of dendritic neuropil, especially in the dendritic branches distant from the cell body (i.e., distal segments), and increases in the number of basilar dendritic segments. The study found, interestingly, that the total dendritic length of tissue from the Wernicke's area of nine-year olds was significantly longer than that of any of the adult subjects. Jacobs and Scheibel suggest that major dendritic development takes place through the first decade of life, followed by a gradual decline of proliferation that approximates adult values late in the second decade. Furthermore, Chugani, Phelps, and Mazziotta (1987) point out that cerebral metabolism (i.e., glucose utilization) as well as the size of the major projection neurons in the cerebral cortex (i.e. pyramidal cells), which are indicators of neuronal activity, appear to show parallel age-related changes, reaching maximum measure roughly by the age of 10. The correspondence between neurobiological maturation and the alleged critical period for language attrition is compelling.

Neurobiological substrate of affect

The role of affect in L2 acquisition and attrition appears to have a neurobiological correlate. The almond-sized mass of nuclei called the amygdaloid complex in the limbic system (i.e., the border area arranged around the junction of the cerebral hemisphere with the brain stem), which is located near the tip of the temporal lobe, has been found to be the mediator of the association of memories

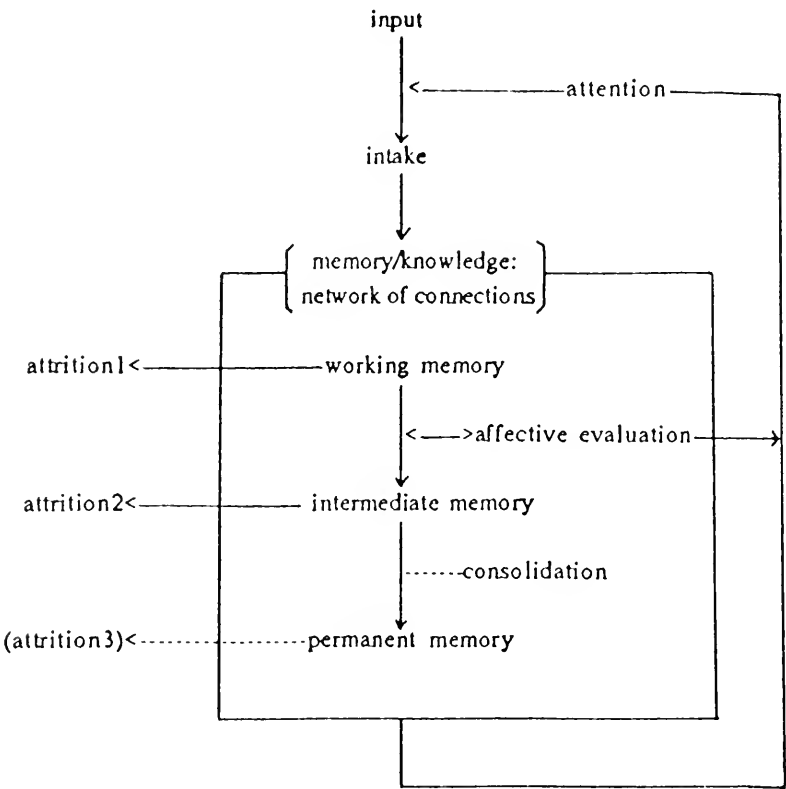
formed through different senses. Although the amygdala in itself is not part of the medial temporal memory system, it establishes links between stimuli through its direct and extensive connections with all the sensory systems in the cortex and attaches affective evaluations to the stimuli. Increased attention to stimuli as a result of the evaluation should lead to more efficient information processing. Thus, it is thought that the amygdala is involved in "selective attention" needed for learning. It appears to limit attention to stimuli with emotional significance (Squire & Zola-Morgan, 1991). The suggestion here is that affect influences what one perceives, and pays attention to, and thus, determines what one learns (Schumann, 1990b; Jacobs and Schumann, 1992) and retains.

Selective attention is relevant in considering why longer exposure to L2 does not necessarily imply higher proficiency and stronger resistance to loss. Studies indicate that cortical network changes are recorded only when input is delivered under attended behavior (Jenkins, Merzenich, Ochs, Allard & Gui-Robles, 1990; La Berge, 1990). Furthermore, it is essential for successful language acquisition and retention that attention be accompanied by sufficient input and use. Based on their experiment on rats, Coleman & Riesen (1968) maintain that certain components of an intact central nervous system may fail to develop normally as a consequence of disuse or decreased input, though there is a degree of dependence on innate organization. Rosenzweig, Love and Bennet (1968) demonstrated that even a few hours a day of removal from impoverished to enriched environment produced significant changes in the brain chemistry and brain weight of rats.

These studies together seem to support findings in language attrition research which indicate that affective factors and selective attention resulting from affective evaluation play significant mediating roles in determining the amount of language use crucial to language retention.

A MODEL OF LANGUAGE ATTRITION

Based upon the integration of relevant issues discussed above, the following schematic representation is presented as a tentative psychological model of the process of language attrition.



Both language acquisition and attrition are consequences of neural plasticity. Neural plasticity allows input to alter the configuration of existing knowledge networks in memory storage. New information is compared with prior knowledge and stored in matched patterns. It is first stored in working memory via modality-specific processing systems, then in intermediate memory where information is integrated and associated with other information, and finally in permanent memory. The transition of information to long-term storage involves consolidation which gradually strengthens certain connections and eliminates or weakens others. Linguistic knowledge represented in eliminated connections is that which is lost. Since memory in permanent storage has gone through consolidation, the connectivity is stronger and, thus, less vulnerable to attrition. Vulnerability to attrition is greatest with respect to recently acquired, unconsolidated knowledge. Information which survives competition and reorganization becomes the basis for the processing of new information.

Figure 1. Neural plasticity allows input to alter the configuration of existing knowledge networks in memory storage. New information is compared with prior knowledge and stored in matched patterns. It is first stored in working memory via modality-specific processing systems, then in intermediate memory where information is integrated and associated with other information, and finally in permanent memory. The transition of information to long-term storage involves consolidation which gradually strengthens certain connections and eliminates or weakens others. Vulnerability to attrition is greater with respect to recently acquired, unconsolidated knowledge. Information which survives competition and reorganization becomes the basis for the processing of new information.

Affect restricts attention to relevant input, and influences the amount of intake. It also determines which information is to be stored in long-term memory. Individual differences in prior experience which define the nature of personal affective evaluations of stimuli determine the formation and strength of connections (i.e., speed and amount of learning), and may even protect certain information (e.g., retention of emotionally laden expressions) during incubation.

The "boxology" adopted in the representation of the model is somewhat misleading since it depicts the types of memory storage as being separate entities. The same synaptic connection within a given neuronal network may correspond to any length of memory storage, depending on the strength of the connections. The psychological terms working, intermediate, and permanent memory, are distinguished, however, in order to reflect the neurobiological findings which indicate presumably separate sites of storage roughly corresponding to the three types of memory.

Affect restricts attention to relevant input and influences the amount of intake. It also determines which information is to be stored in long-term memory. Individual differences in prior experience which define the nature of personal affective evaluations of stimuli determine the formation and strength of connections (i.e., speed and amount of learning), and may even protect certain information (e.g., retention of emotionally laden expressions) during incubation. Thus, length of exposure alone does not necessarily determine proficiency or achievement.

Certain groups of connections form a system which becomes the unit for higher-order connections. Different systems have different critical periods of development, and input during such periods has the greatest influence on the nature and structure of connections to be formed. Little is retained if input is received only during the immature stages of the relevant system that processes and stores that kind of input.

A theory of language attrition should subsume or be compatible with a theory of language acquisition (Schinke-Llano, 1989). The present model, accordingly, assumes that the biological mechanism that governs language acquisition and attrition in both L1 and L2 or, for that matter, in any language, is by and large identical. Differences in the characteristics of the actual behavior observed in language acquisition and attrition, or in L1 and L2, are mostly due to the different environmental factors that have contributed to the formation of idiosyncratic neurobehavior at different developmental stages and under different affective conditions. Connections are input-dependent, but the mechanism that keeps records of the input and retains them in long-term memory in association with other input items, features, or relationships may be innate.

Although the present model is a psychological one, the intention has been to emphasize the significance of considering available information from neurobiology and relating that to psycholinguistic research on language attrition. With further advances in neurobiological studies, the construction of a

neurobiological/neuropsychological theory of language acquisition and attrition should become feasible.

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NOTES

¹ The loss of L2/FL can further be subcategorized into two types; L2/FL lost in the L2 environment such as in the case of aging emigrants/immigrants, and L2/FL lost in the L1 environment such as in the cases of language learners at school of returnees from countries where the FL is spoken.

Language attrition studies may ultimately need to distinguish the two types of language learning. There is, however, not enough literature on language attrition that makes the distinction feasible at this point. Furthermore, my view on language attrition is that the governing mechanism of linguistic behaviors is identical whether the language is L1, L2, or FL. I will argue later in the paper that what makes the difference are the cognitive, developmental, socio-psychological, and environmental factors that are concomitant to the L2/FL distinction. Thus, in the present paper, I do not intend to make an explicit distinction between L2 and FL loss.

² This section is a condensed version of a lengthier and more comprehensive review of literature of L2 attrition summarized in Yoshitomi (1992). Some oversimplifications of issues were inevitable due to the specific focus of the present paper and space limitations.

³ Although a more detailed discussion of the investigation of language abilities in brain damaged persons in relation to language loss would be a useful exploration, this paper will limit itself to a brief mention that intriguing similarities exist between pathological and non-pathological language less. Future research should certainly address this issue further.

⁴ For more discussion on selective attention, see Sato and Jacobs or Lem, this volume.

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Asako Yoshitomi holds an M.A. in Linguistics from Sophia University and is currently a Ph.D. candidate in Applied Linguistics at UCLA. Her interests are in first and second language acquisition, language attrition, TEFL, and teaching Japanese as a foreign language.

EXCHANGE

Connectionism: Explanation or Implementation?

Cheryl Fantuzzi
University of California, Los Angeles

Although purely empiricist, or environment-based, theories of language acquisition suffered some serious setbacks with the rise of generative grammar, they have very recently come into vogue again with a new brand of cognitive modeling known as connectionism. Connectionism represents the strongest form of empiricism: radical connectionists typically argue that all learning is based on the processing of input, and that there is no need to posit any a priori internal structure to the processing system at all. What linguists describe as rule-governed behavior, radical connectionists say is only a description of the emergent behavior of the processor. Learning is simply a matter of strengthening and weakening neural connections in response to the statistical frequency of patterns in the input, and the abstract symbols and rules that are so crucial to current linguistic theory have no place at all in a connectionist system. There have been varied responses to these strong claims. Some have been wildly enthusiastic about the new approach (e.g., Sampson, 1987) while others have severely criticized many of its claims (e.g., the papers in Pinker & Mehler, 1989). There is also an extensive middle ground between the two extremes however. While "pure" Parallel Distributed Processing (PDP) models seem to work best with problems involving motor control or the earliest stages of visual processing, connectionists working with more complex cognitive processes such as language or problem solving have often incorporated symbols into their connectionist architectures (e.g., the papers in Hinton, 1991).

There has recently been some interest in the applicability of connectionist models to Second Language Acquisition (SLA) theory and research (Schmidt, 1988; Gasser, 1990; Sokolik, 1990). In the last issue of *IAL*, Yas Shirai (1992) added his voice

to this growing literature by arguing that the connectionist framework effectively explains L1 transfer in SLA. He also argued that since connectionist models present a more neurally plausible model of the lower-levels (i.e., neural level) of language processing, they may provide second language researchers with a new opportunity to look inside "the black box" of language behavior. In this special issue on neurobiology and language, it seems particularly appropriate to take a closer look at just how neurally plausible connectionist models are, and if connectionism adequately explains all of the transfer phenomena that Shirai claims that it does. While Shirai and I are in agreement on the need for a general cognitive model of SLA which integrates research in several fields (Fantuzzi, 1989, 1990; Hatch, Shirai & Fantuzzi, 1990), I disagree that connectionism can yet explain the high-level transfer phenomena that Shirai outlines in his article.

More than simply reply to Shirai's claims for a connectionist explanation of language transfer, I will also look more closely at what a connectionist explanation of a cognitive function entails. McCloskey (1991), for instance, argues that "connectionist networks should not be viewed as theories of human cognitive functions, or as simulations of theories, or even as demonstrations of specific theoretical points" (p. 387). An important question, then, is precisely what role connectionism plays in the development of cognitive theories and in the explanation of linguistic phenomena, a question which is of course frequently raised in the connectionist literature itself (e.g., Smolensky, 1988; Fodor & Pylyshyn, 1988; Pinker & Prince, 1988; Minsky & Papert, 1988; McClelland, 1988). This requires a closer and more critical look at some existing connectionist models of language functions than Shirai has given.

PRACTICING CONNECTIONISM WITHOUT A CONNECTIONIST MODEL

Shirai largely relies on one particular implementation of a connectionist model to support his argument that the connectionist framework can provide an explanation for language transfer. This model is Gasser's (1988) localized model of bilingual sentence production. However, he also liberally peppers his discussion with references to other models (including Gasser, 1990) and to a general "connectionist framework". This reference to a generic

framework, however, ignores the important differences between the many different types of models, and evades deep discussion of their actual capabilities. Gasser (1990), for example, explicitly points out that connectionist models can not yet model "stages" of acquisition, or environmental factors or monitoring, and it is unclear how they could. Yet Shirai lists discourse/pragmatic knowledge, sociolinguistic context, learning environment, level of proficiency, markedness, age, attention, and monitoring all as conditions on transfer that the connectionist framework can "effectively explain."

As a representative sampling of Shirai's arguments, in this section I will discuss and critique his proposals for modeling the effect of the learning environment, level of proficiency, and sociolinguistic context on L1 transfer. Section 2 will focus on the general issue of the role that connectionist models play in developing theories of cognition. In section 3, I will take a closer look at the claim of neural plausibility, and discuss how connectionism has been used to model age-related conditions on learning. Section 4 concludes that Shirai has not demonstrated how connectionism may provide SLA researchers with new and more sophisticated interpretations of language transfer or new insights into the role of Contrastive Analysis (CA) in predicting language transfer. In my opinion, the precise role that connectionist models of cognition might play in SLA research, beyond Gasser's (1990) first noteworthy attempt, has yet to be articulated.

Learning Environment

Shirai argues that connectionism explains transfer in the classroom setting in that an acquisition-poor learning environment tends to result in a "grammar-translation" approach, which "necessitates that the learner 'connect' L1 to the L2." In naturalistic settings, learners who have little knowledge of L2 and must communicate also "have to make L1-L2 connections between lexical concepts. As a result of this process, L1-L2 connections become stronger and harder to eliminate later" (p. 105). This discussion of learning environment is typical of how Shirai treats most of the conditions on transfer: there is a strong connection between L1 lexicon/L1 concepts and L2 lexicon/L2 concepts, and if L1 concepts are activated while speaking L2, L2 performance will be influenced by L1. The connectionist model implements this via a highly interconnected network of spreading activation. The

details of the implementation, however, are not given, and many other questions remain unanswered: if transfer is simply the consequence of L1-L2 connections between lexical concepts, when does transfer not occur? Is the strengthening of connections merely a matter of stimulus-response? If these strong connections are hard to eliminate, how is the L2 ever learned? While it is an open question whether connectionism can address these issues or not, possible answers could only be contained in a specific model. As will be discussed further below, the model that Shirai uses to illustrate his argument was not designed to handle this particular problem.

Shirai himself points out in another section that L2 learners in both classroom and naturalistic settings are strongly guided by conscious strategies, but conscious following of rules is difficult for connectionist models to handle. Since grammar-translation, as much of L2 learning, appears to involve conscious strategies and rule-application, it is not clear just what aspects of transfer connectionism explains. Again, the assertion that transfer occurs because L1 is somehow connected to L2 and activated with language input is abstract enough to be modeled in many ways. A specific model adds the crucial details of how information may be represented and processed, but Shirai's purported explanation for how these conditions might be modeled is very broad and vague.

Level of Proficiency

As another condition on transfer, Shirai notes that a learner of lower proficiency must fall back on L1 syntax. When there is little syntactic knowledge of L2 and the speaker has to say something, she will simply plug L2 words into L1 structures, a process known as "relexification." Transfer thus occurs because the learner must activate her knowledge of L1 in order to produce L2. Here, Shirai explicitly invokes Gasser's (1988) model to explain the phenomenon. In Gasser's model, syntactic information in L1 is partly determined by the lexicon (as in traditional linguistic theory) and by a "sequencing component." The sequencing component is not directly involved in transfer, but is simply necessary for this network to produce sentences at all. Therefore, relexification occurs in the model because general linguistic structures exist and are accessed for both L1 and L2, and when the L2 is less developed, L1 structures are accessed. Proposing general syntactic structure in linguistic representation, however, is not unique to Gasser's model but is, of course, found in many

non-connectionist models as well. Again, we have not been shown how connectionism provides a superior account of language transfer.

Sociolinguistic Context

Although he gives us only a partial description of a particular localist model which generates a few simple sentences and cannot model all of the transfer phenomena he describes, Shirai's claim is that the model could be easily augmented to handle it. An example is his discussion of how "sociolinguistic context" aids transfer: "when the learner is speaking with someone from the same culture, the hearer-role (represented as a node) is specified as such. Whether the learner likes it or not (i.e., is goal-driven or not), the hearer-role is activated, which leads to a spreading activation of the nodes connected to it. Thus, the model would be able to show the kinds of adjustment which are called 'accommodation'" (p. 109). An example of accommodation is the observation that native Chinese speakers show more L1 influence when speaking in Thai with other native Chinese speakers than with a Thai speaker. Shirai is not suggesting that the "hearer-role" node alone explains accommodation, but there must be many more nodes connected to that one which must also be specified in the model.

Since all of the connections in Gasser's model have been set by hand, to augment it to show language accommodation would require specifying what the appropriate "sociolinguistic context" for the transfer is, all of the relevant social or cultural information that the hearer-role node is connected to, and all of the connection weights as well, including of course when the hearer-role's effect on transfer would be overridden since the hearer-role must always be activated in a bilingual. This, however, is not a trivial task, considering that a *single sentence* in the model required 292 nodes and 1374 connections!

While Gasser's model might be augmented to incorporate more complex information, it is still not clear how much the transfer phenomena would be explained by it, since the hand-set connections really instantiate the programmer's assumptions of how information should be represented in order to perform a certain task. Consider the example of code-switching that Shirai uses to illustrate the model's general processing style. Gasser cites a case in which a Japanese speaker inserts an English word, "spoil", into an otherwise Japanese sentence, presumably because

the "connections" from this concept to linguistic expression are stronger to English than to Japanese (*ano okanemoti wa ozyoosan o spoil sita*, 'That rich man spoiled his daughter,' Gasser, 1988, p. 7). In order to model this behavior, Gasser manually set the connection "weights" so that the English word 'spoil' was stronger than the equivalent Japanese expression, and was thus naturally chosen. Gasser's point in presenting this example was not to demonstrate transfer (which is after all only a general side effect of the processing style), but, rather, how a single concept ('spoil') may map into more than one linguistic structure in the model. These linguistic structures were also specified beforehand by Gasser, through use of such high-level linguistic constructs as "transitive clause," "direct object," and "verb".

Although learning is an important component of transfer, Gasser's model does not actually learn its own representations. However, Shirai speculates on how the connections to 'spoil' may have been acquired: "if a Japanese-speaking learner of English keeps saying 'spoil' instead of 'amayaku', the association will be stronger, and it will be easier for him to say the word when speaking English. This process would constitute learning the word 'spoil' for the learner" (p. 97). As in the earlier examples, though, the argumentation is circular, and Shirai has in effect just restated the problem to be explained. How did the learner acquire the word "spoil" in the first place? How are associations formed, strengthened, or weakened? How are words or sentences actually represented? How may this be implemented in a real brain?

While Shirai uses Gasser's model to broadly illustrate connectionism, Gasser (1988) himself says that his "localized" model is unlike most connectionist approaches in that he started out with the sorts of representations that one would find in a symbolic model, such as linguistic "schemas", and nodes for NPs, direct objects and accusative case. He then implemented them in a connectionist network to see if simple bilingual sentences could be generated with this new processing style. Certain desirable properties, such as automatic generalization and cross-linguistic transfer, come with this type of processing for free. "Pure" connectionist systems, which use fully distributed representations, do not start with such high-level constructs, but develop their own representations. However, these networks cannot perform very complex linguistic tasks, and, as noted above, connectionists working with language often use the more traditional approaches or theories implemented in a connectionist processing style—in other words, hybrid models.

To sum up the discussion so far, I have argued that Shirai has presented neither a clear account of the particular language transfer phenomena to be explained nor a model that would be able to implement such a theory if it existed. As Boden (1990) points out, any computer model, whether symbolic or connectionist, cannot embody a psychological theory without having a theory to begin with. Connectionists have had more success with modeling low-level aspects of vision because neural theories of low-level visual processing exist. The very early stages of visual processing are known to involve massively parallel neural computation, which is suitably implemented within connectionist networks. There is no connectionist theory of language as yet, although traditional linguistic theories of competence and performance work well with more traditional forms of computing in Artificial Intelligence (AI). The next section considers how connectionist models might help to develop such a theory.

CONNECTIONISM: IMPLEMENTATION OR EXPLANATION?

An ongoing debate in the AI literature has been whether a computer simulation of human intelligence may constitute an explanation of it (see, for example, the exchange between Searle, 1990, and Churchland & Churchland, 1990). Some critics of conventional AI as a model of human cognition see connectionism as a more neurally plausible glimpse into the "black box" (e.g., Churchland, 1986; Dreyfus & Dreyfus, 1985), and Shirai is clearly a proponent of this position. However, as we saw above, Shirai merely points to a vague connectionist framework to support this point of view. In this section, I will raise some general problems with viewing connectionist modeling as an explanation of cognition, although it could play a role in developing a theory. My own view is that connectionist and symbolic models are both useful for studying different aspects of cognitive processing.

This, of course, runs counter to Shirai's enthusiastic presentation of connectionism as a potential "paradigm shift" in psychology and linguistics, a proposition that I feel is not only fundamentally misguided, but also unproductive for the field. Shirai fails to mention, for instance, that Clark (1989) considers such polarization to be "an extreme danger" to the cooperative efforts of cognitive science. While Shirai notes that the

mechanisms by which a connectionist system might handle conscious rule-learning are "unclear" (p. 108), he relegates Clark's own proposal for a hybrid model to a footnote (but see Fantuzzi, 1991), and says that he argues strongly for the more radical approach "because it offers a new perspective" (p. 114).¹ However, even a radically new perspective does not constitute a paradigm shift and, at the very least, connectionism may be integrated with traditional symbol systems, if not viewed as simply implementing them. The mere existence of hybrid models invalidates the claim that these are separate paradigms, and the vast majority of connectionists see themselves as building upon rather than supplanting previous work (see Boden, 1990, for an excellent review and a discussion of this issue). At any rate, there is just no evidence as yet that connectionist models can provide a better account of linguistic phenomena than symbolic models do.

An argument is typically made that parallel distributed processing is more brain-like than traditional AI computing because serial computations in the brain would take too long, and highly interconnected and redundant connectionist processing units are more like real neurons in that they display graceful degradation rather than complete disruption if one part of the system fails (e.g., Feldman & Ballard, 1982; Sokolik, 1990). However, these and many similar arguments have been countered as being mere details of implementation, and not a principled distinction between connectionist and symbolic models of cognitive processes (Fodor & Pylyshyn, 1988). Many point out that localist connectionist systems are not fundamentally different from symbol systems, since both store patterns representing symbols in the network (e.g., Fodor & Pylyshyn, 1988; Bechtel, 1987). The model on which Shirai bases most of his discussion is of course such a model. Whether or not there are also explicit rules represented in the system is not necessarily a central issue for linguists (Fodor & Pylyshyn, 1988; Stabler, 1983).

The more radical fully distributed connectionist models *do* offer a clearer alternative to symbolic AI since they do not distinguish representations (symbols) from the physical functioning of the system itself (Cummins & Schwartz, 1987). However, an important question is how well these systems can handle complex phenomena such as language. While simple pattern association may be one part of language learning, it is hard to see how sentence structure and abstract symbols such as NP can be completely absent from it, and the current state of connectionist research gives us no reason to discard them. Pinker and Prince (1988), for

example, convincingly argue that children's double-marking errors (*wents*, *thoughted*) are not due to pattern blending, but to the inflection of the wrong stem, although the notion of "stem" or "affix" is unrepresentable in a connectionist system. Kim, Pinker, Prince and Prasada (1991) demonstrate that a native speaker's representation of past tense formation includes the intuition that denominialized verbs take the regular past by default (*The football player grandstanded to the crowd; The baseball player flied out to left field*). This also is unrepresentable in a "pure" connectionist system.²

Because fully distributed connectionist systems cannot handle structured knowledge very well, connectionists working with complex problems of language often incorporate symbols into their connectionist architectures (Hinton, 1991). Cummins and Schwartz refer to this type of model as "conservative connectionism," and Pinker and Prince (1988) refer to it as "revisionist-symbol-processing connectionism," as opposed to the radical "eliminativist" position that Churchland (1986) or Shirai advocate. It has even been suggested that this dual-mode of processing may reflect the different types of processing that people seem to do (Schneider and Schiffman, 1977; Schneider, 1987, 1988; Clark, 1989). When symbols are distributed over many units, one gets the same performance benefits that one has with a connectionist system: robustness, redundancy, resistance to noise or damage, automatic generalization and so on (Fodor & Pylyshyn, 1988), including the sort of transfer effects that are seen in Gasser's (1988) localist model.

One problem with claiming that the fully distributed models can explain a certain phenomenon (a problem that one doesn't have with symbolic models) is that it is difficult to see exactly how the distributed models arrive at their solution. Hinton (1991) points out that when there are several hidden layers, as there are in many of the learning networks, it is hard to say what each hidden unit represents. Although the system arrives at a solution to its task, even its designer does not know how it has done so, and an "existence proof" that a model can perform in a certain way is not a good "explanation." As Klein (1990) notes:

Connectionists make models tick, but do not make us understand as yet what makes them tick. Turning now to SLA more specifically, we do not just want a network which, when fed with sufficient input in the form of sentences, provides us with the appropriate regular and irregular

morphology. We want to know the principles according to which the human mind breaks down the sound stream into smaller parts, assigns structure and meaning to these, retreats from false generalizations, and the like. (p. 226)

Clark (1990) uses the text/phoneme conversion model, NETtalk (Sejnowski & Rosenberg, 1986), to illustrate this problem. While the model does not encode traditional phonological rules, it is given a rich prior analysis of its domain through the choice of input and output representation, hidden unit architecture and learning rule. Although the network was 95% successful in its task of converting text to speech after 50,000 trials of "supervised" learning, even its designers don't know how it actually performed the task, and Clark discusses various strategies that have been used to investigate how it was done, and to try to discover the principles by which the system arrives at its solution.

McCloskey (1991) makes essentially the same kinds of observations about Seidenberg and McClelland's (1989) connectionist model of word recognition and naming. He argues that theoretical proposals for cognitive functions, tied to specific descriptions of particular networks, are too vague to be explicit theories of cognitive functions, although they are valuable tools for developing theories. For example, while the performance of Seidenberg and McClelland's model matches the performance of human subjects, the authors cannot specify the things that a theory should specify: what regularities and idiosyncrasies of the orthographic and phonological representation of words are encoded by the network (i.e., how do people encode the different representations of the letter *a* in various contexts); how the acquired knowledge is actually represented in the network; and how the propagation of activation throughout the network results in the appropriate representation being chosen in the appropriate context (e.g., the appropriate *a* in *hat*, *hate*, *have*). While Seidenberg and McClelland have provided an explicit computer simulation of a cognitive behavior, McCloskey argues that the underlying theory of human cognition remains vague: just general statements to the effect that representations are distributed and similar words are represented similarly. The problem is that the dynamics of complex nonlinear connectionist systems are difficult to analyze, and thus to understand. Unless one is satisfied with an "existence proof" that something can be modeled, the models still do little by way of explaining the behavior. They again provide a

"black box" simulation of a cognitive behavior rather than a theory of it.

Another important difference between connectionism and traditional AI, then, is the way that each constructs theory:

The connectionist, by whatever means, achieves her high-level understanding of a cognitive task by reflecting on, and tinkering with, a network which has *learned* to perform the task in question. Unlike the classical Marr-inspired theorist, she does not begin with a well worked out (sentential, symbolic) competence theory and then give it algorithmic flesh. Instead she begins with a level-0.5 theory, trains a network, and then seeks to grasp the high level principles it has come to embody. (Clark, 1990, p. 303, emphasis his)

Thus, having built a distributed network which successfully completes a certain task, the next problem is to seek to understand the principles that caused the behavior, the same task facing a neuroscientist who studies a real neural network. Clark uses the term level 0.5 theory (as opposed to level 0, which is no theory at all and level 3, which would be a high-level competence theory) to refer to the fact that some amount of theory must be used to set up the program in the first place. Differing amounts of a priori theory may be applied to set up a program, but they all make some initial assumptions, even if it is only which features will be represented on which units and how many units or hidden layers are needed to do the task.

One important issue may be the "psychological reality" of these assumptions. Pinker and Prince (1988) and Lachter and Bever (1988), for example, presented a sharp critique of the assumptions underlying Rumelhart and McClelland's (1986) past tense acquisition model. Clark (1990) points out that even when the initial assumptions are minimal, they may be psychologically unrealistic; for example, the amount of units used and the best form of the solution must be specified beforehand. Another question about the psychological reality of connectionist systems that linguists often raise is the assumption that there is an explicit "teacher" which looks at the output and incrementally corrects it, a quite implausible suggestion for first language acquisition.

Fodor and Pylyshyn (1988) argue forcefully that connectionism may at best provide an account of the "abstract neural" structures in which symbolic "cognitive structures" are implemented, each thus representing a distinct level of cognitive

modeling. But then again, the tasks that these distributed models can perform, such as transcribing text to speech, adding phonological past tense endings to verbs, or recognizing words from non-words, are not the sort of complex linguistic problems which usually occupy linguists. Furthermore, the behavior of the models doesn't always match human behavior (for discussion see Pinker & Prince, 1988). Clearly, what connectionist models may someday teach us about how humans process language is still very much an open question.

McCloskey (1991) suggests that connectionist models may be viewed as "animal models" of human functions. He argues that an animal model is not itself a theory or a simulation of a theory, but an object of study which may lead to theories of human systems. In the same way, artificial neural networks may also be easier to study and analyze than actual brains, and thus may one day help to develop a theory of human processing, although there is no connectionist theory of cognition as of yet. As Clark says, explanation in connectionism requires, at the minimum, "reflecting on, and tinkering with, a network which has *learnt* to perform the task in question" and then seeking the principles it has come to embody. Arm-chair speculating on the future capability of models, as Shirai does, certainly will not explain issues in SLA. A clearer discussion of theory, explanation and of the underlying assumptions and actual capabilities of existing models must be present in any discussion of the applicability of these models to SLA research.

This section has pointed out some problems with viewing any connectionist model as an "explanation" of linguistic phenomena and takes issue with Shirai's presentation of connectionism as a potential paradigm shift in cognitive modeling. The next section considers how neurobiologically plausible the models are.

CONNECTIONIST MODELS AND NEURAL PLAUSIBILITY

As Rumelhart and McClelland (1986, Part V) point out, connectionist models are considered to be neurally plausible to varying degrees. While certain models of psychological processes, such as Gasser's (1988) sentence production model, are "neurally inspired," one could say that this inspiration is minimal

(Schumann, 1990a). Some connectionist models are much more biologically-oriented, such as Munro's (1986) model of the development of ocular dominance in the visual cortex, and this model will be discussed briefly below.

The Neural Plausibility of Connectionist Algorithms

As noted above, some connectionist learning algorithms have been criticized as being psychologically implausible, since they rely heavily on constant feedback from an external "teacher" who knows what the correct answer should be. One widely-used learning algorithm, known as back-prop, is criticized as being neurally implausible as well, because real neurons do not feed error information back down the neurons so that they can re-adjust their connections (Thorpe & Imbert, 1989).

Shirai describes memory and learning in very general terms: as the strength of connections between "nodes" in a network and the "activation" and "firing" of patterns of nodes. Transfer is the selection of a pattern of nodes that are more strongly associated with an input representation. He describes learning in the connectionist model in this way:

Essentially, the more often a particular node at the ends of connections are activated and/or fired, the stronger the connections become; consequently stronger connections become more easily activated, and this greater ease of activation causes more learning. (p. 96)

This corresponds to the very simplest learning algorithm, known as the Hebb rule, which is indeed an abstraction of actual neuronal processing (Hebb, 1949). McClelland, Rumelhart, and Hinton (1986) describe Hebbian learning in this way: "When unit A and unit B are simultaneously excited, increase the strength of the connection between them" (p. 36).

This rule may be adjusted to cover both positive and negative activation values (excitation and inhibition). However, McClelland and colleagues go on to say that because the Hebb rule has some limitations, most connectionists do not generally use it in this form for more complex computations but have devised more sophisticated learning algorithms, such as the "delta rule" (which Sokolik 1990, discussed below, uses) and "back-prop", (which Gasser 1990 uses).

While there does seem to be neurobiological support for Hebbian learning, it is unknown how much this very simple type of associative learning, which is observed in simple slugs responding to electric shocks, is involved in higher cognitive functions. Nevertheless, Shirai describes complex human learning in such simple terms. For example, as slugs "learn" to associate shocks with light, Shirai talks about people learning to associate L1 concepts/words with L2 words through the simple strengthening of connections. While we certainly cannot say that some human learning is *not* due to this type of conditioning, it may be a leap of faith to attribute complex language learning or language transfer to simple associations between simultaneous inputs - especially in light of the enormous difficulties connectionist systems have in representing complex linguistic knowledge and, of course, the many convincing arguments from generative linguistics to the contrary. Shirai himself brings up the point that Chomsky (1957, 1959) effectively defeated the behaviorist paradigm, but offers little compelling evidence that a neo-behaviorist revolution is in the making.

According to Shirai, once L1 connections are "formed and solidified as a system," subsequent alteration of connections may become difficult (p. 107). He relates this to the notion of unitization (Kennedy, 1988) at the information-processing level: once knowledge becomes automatized and "solidified" as a unit it is difficult to alter later. However, how connectionism explains age-related transfer at either the so-called neural (connectionist) or psychological level is again quite vague. Although he suggests that "frequent" or "salient" or even innate connections may become "too strong to alter later in life" (p. 103), we are still faced with the problem of how connections are formed, how later learning occurs, how a crucial balance is maintained between the malleability and rigidity of connections, and how real neurons function. Shirai refers to Munro's model of the development of the visual cortex as a possible connectionist explanation of "age-related" conditions on transfer, but offers no discussion of it.

Munro's Model of a Critical Period for Visual Processing

Munro (1986) presents a mathematical model of a specific neural system whose circuitry is relatively well known, the visual cortex. He argues that the degree of plasticity in single neurons may reflect sensitive periods in learning, although sensitive periods

do not necessarily reflect decreasing plasticity in neurons. Munro does not propose that existing neural connections may become "solidified" or difficult to modify, but that uncommitted neurons will naturally change their state more rapidly and easily than already committed neurons. Further, he suggests that this type of plasticity may hold only for the earliest stages of cognitive processing, which in the domain of language acquisition might be phoneme recognition, and that higher cognitive processes may not show a sensitive period at all. This is of course an empirical question. Whether Munro's framework might be applied to cognitive systems more generally, and to issues in language acquisition in particular, remains an open question. However, the connection that Shirai attempts to make between Munro's model and issues of transfer in SLA is pitched at much too general a level, which is, simply, that a reduction in the modifiability in neural connections might be one factor leading to a sensitive period for some language functions. We then need to ask which functions, which neurons, why, and how.

Sokolik's PDP Model for a Critical Period in SLA

Munro's approach to modeling a critical period for the visual cortex may be compared with an explicit PDP model of age-dependent conditions on language acquisition that has been proposed in the SLA literature. Sokolik (1990) notes that a protein known as Nerve Growth Factor (NGF) is thought to be linked to rate of learning. If children have a higher amount of this protein than adults, and we assume that NGF affects the ability to learn languages more quickly, then we have a principled physiological basis for setting the "learning rate" in a connectionist algorithm higher for children than for adults. Set at a higher value, a PDP model will learn more quickly, which, Sokolik suggests, may offer an explanation for why children acquire second languages "more readily" than adult language learners do.

Sokolik presents an example in which the learning parameter for the acquisition of a certain feature is set higher in the child PDP model than it is in the adult PDP model. The child model, therefore, attains near mastery of the feature more quickly than the adult model. However, there are at least three problems with this scenario, other than the psychological reality of the learning algorithm itself, as discussed above. Sokolik herself mentions that the significance of NGF to learning rate is speculative, and ignores other factors that may be involved in

variable learning for adults, such as psychological and sociological factors (Schumann, 1990b). A second problem is that much empirical research has suggested that adult language learners may at first be quicker at acquiring a second language than children, but that children overtake them in the long run (Long, 1988). A third problem is that, even at the level of the single neuron, assuming that NGF is a factor in learning rate is simply an ad hoc explanation of critical period effects. Munro contrasts his own position with the popular idea that the neurotransmitter norepinephrine might act as a global modulator of neuronal plasticity and thus account for lower learning rates. He points out that one may always simply add an explicit learning rate into one's learning rule in order to obtain certain pragmatic results, or factor in global modulators which affect the learning rate, but this is unnecessary. As we saw above, his solution for a critical period is simply that uncommitted neurons form their connections more easily. But again, the translatability of his particular model to language acquisition issues is not straightforward.

What the above discussion makes clear is that the focus of Sokolik's and Munro's PDP models is not on how proficiency changes as a result of changes in the form of the mental representations, but as a result of a change in a learning rule, or in the weights and connectivity of the processing units themselves. A connectionist system is, as Bialystok (1990) points out, the quintessential processing model. But since the models only apply to on-line processing (e.g., learning) and do not apply over time (i.e., to development), they perform quite different tasks than competence models, which are concerned in detail with changes in structured mental representation. Therefore, Bialystok argues, PDP models may be construed as models of processes rather than of the mental representations which are the focus of competence theories. The two approaches, representing different sides of the competence-performance distinction, may eventually co-exist as complementary explanations for different problems.

The important point is not to maintain a strict dichotomy between performance and competence, of course, but to realize that different aspects of cognitive modeling may be reconciled into one whole. This directly relates to the issue of "levels" of explanation mentioned in the last section. The descriptions of cognitive behavior at the level of neural processes, of connectionist networks, or of competence theories may be viewed as different levels of abstraction (Fodor & Pylyshyn, 1988). Clearly, we are not yet at the point where we can say that connectionism, itself an

abstraction of neural processing, will ever be able eliminate the higher levels.

CONCLUSION: CA REVISITED

It appears that the general thrust of Shirai's article is to revive a Contrastive Analysis (CA) approach to transfer by buttressing its theoretical framework with connectionism. This topic alone is a broad one, and by focussing on it Shirai may have been able to cover at least one area of his article in more depth.

A radical connectionist approach, which Shirai clearly favors, is incompatible with parameter setting (White, 1985, Flynn, 1987; Hilles, 1986) or with a learner's own internal contribution to learning (e.g., the natural order hypothesis in the acquisition of morphemes). Indeed, Shirai suggests that "natural order" phenomena "can be explained by 'naturalness' factors such as perceptual saliency, frequency and invariance of forms, as well as by the 'L1' factor." As he puts it:

In connectionist terms, such a claim can be interpreted as follows: the naturalness factor makes it easy for a particular form to be connected to a particular meaning/function. It will be easy to identify and easy to match; there will be many opportunities to strengthen connections. This will result in the Natural Order. (p. 100)

However, this explanation completely sidesteps the problem of what is meant by "salient" or "easy" to map, why some frequent items are not learned first, how this mapping is done, etc.—that is, all of the issues that are of interest to SLA researchers. While the simple mapping strategy that Shirai describes is intuitively plausible, it is notoriously difficult to establish causal relations between these "naturalness" factors and language acquisition, as the wide literature on morpheme acquisition shows. Also, as Larsen-Freeman and Long (1991) point out, the claim that morphological development shows much commonality across unrelated languages, pointing to some internally driven organization of input, has simply been too well documented to be ignored.

In a similar vein, Shirai argues that connectionism explains "interlingual" mapping between L1 and L2 because "when

a new pattern is encountered which is similar to another existing pattern in the learner's representation, the new pattern would activate the existing pattern" (p. 111). How similar must they be to be activated? What defines similarity? Why are some items not transferred but learned? What happens in the network if patterns are not similar?

Gasser (1990), of course, has applied the "connectionist framework" to an actual test of the CA hypothesis. One thing that he found was that the learning performance of the model was more complex than "traditional" CA would predict, namely that all differences between L1-L2 should be equally difficult to learn. The independent variables of L1/ L2 that Gasser modeled (word order and lexical form) in fact showed an effect of interaction. While he admits that the conditions of the model were a gross oversimplification of an actual language learner's task, Gasser notes that:

(W)hile these results should be regarded very tentatively, they point to a possible line of connectionist research, one in which networks test out particular hypotheses about transfer and suggest what types of data are needed to flesh out the transfer picture. The main conclusion to be drawn from these simulations is that, even with this extremely simple model of the transfer process, it was impossible to predict precisely how the network would behave. Thus simulations have an important role to play. (p. 196)

While connectionist networks may indeed provide new ways of testing our hypotheses about language processing and learning, simulations serve to help develop and refine our theories of language, not to eliminate them. The connectionist approach as Shirai describes it does not provide new and more sophisticated interpretations of language transfer or new insights into the role of Contrastive Analysis (CA) in predicting language transfer. The role of CA, and the connectionist explanation of transfer, are treated with the same brevity and superficiality as is his discussion of the connectionist framework itself. While Shirai has given us an informative overview of the conditions thought to influence transfer in SLA, its tie-in to connectionism may have benefitted from a more narrow focus, perhaps a closer look at Gasser's (1990) connectionist model of transfer and a more detailed discussion of its implications for a CA position than Gasser himself provides.

As has been made abundantly clear throughout this paper, I believe that Shirai's claim for a connectionist explanation of transfer is greatly overstated. Second language researchers who are to start research projects in the connectionist framework will need to know more precisely how models work and how they may be applied to particular problems. I am of the opinion that connectionist models will probably never replace higher-level explanations in cognitive modeling, although they may help to develop theories at the level of implementation.

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NOTES

¹ Indeed, his token references to some potential compromises belie the obvious prominence given to the "alternative view" throughout the paper. He appears to treat the distinctions between various types of connectionist models as some irrelevant detail.

² Although attempts have been made to improve the original model which was the focus of Pinker & Prince's extensive criticisms, these particular problems have not been addressed; indeed, that would require adding symbols to the network.

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Cheryl Fantuzzi is a doctoral student in applied linguistics at UCLA, specializing in second language acquisition. Her special interests include research in cognitive science and developmental psycholinguistics.

REVIEWS

Why More English Instruction Won't Mean Better Grammar by Charles James N. Bailey. Hawai'i: Orchid Land Publications, 1992. 36 pp.

Reviewed by
Eduardo D. Faingold
State University of New York at Stony Brook

Bailey has written extensively on foreign language teaching and applied linguistics, as well as on linguistic theory and the interface between all these areas (e.g., Bailey, 1982, 1985, 1987). *Why More English Instruction Won't Mean Better Grammar* (WMEIWMBG) is an important contribution to the areas of English language and grammar teaching because it presents a systematic analysis of a wide range of grammatical phenomena where none has previously been apparent and applies modern linguistic concepts and devices to grammar construction (e.g., developmental linguistics, generative grammar, and sociolinguistics). WMEIWMBG is addressed primarily to teachers of English (and to grammarians) and has recently been added to the ERIC list of the U.S. Department of Education. A number of the issues discussed in this work are dealt with in greater detail and from a more linguistic perspective in Bailey's (forthcoming) book.

WMEIWMBG is divided in four chapters followed by one appendix. Chapter 1 presents a systematic account of a wide range of English grammatical phenomena which, according to Bailey, are neglected by most grammarians. He does not mention which grammars he has in mind. The structures discussed by Bailey include (not necessarily in this order): (i) rules governing the use of prepositions, including those for placing prepositions before relative and interrogative pronouns; (ii) rules for the use of interrogative and personal pronouns, as well as for the deletion of non-demonstrative *that*; (iii) a systematic characterization of the English verb, including present, past and timeless tenses, infinitives, participles, and gerunds, as well as the pragmatic (rather than grammatical) use of *go* and *get*, the elided and unelided forms of *have*, *do*, and *got*, and *here's*, *there's*, *where's* with plural predicates; (iv) principles for

distinguishing adverbs having and not having the ending *-ly*, and the genitival forms *'s* and *of*; and (v) a clear and systematic analysis of mass nouns, abstracts, collectives, and generics, as well as substitution and deletion rules changing lexical forms in various ways.

Chapter 2 discusses Bailey's concept of grammatical system with particular reference to the English verb. Rather than the loosely connected lists of unrelated tenses found in many grammars, the English verb is analyzed here as a structure of forms derived with explicit principles from a common, but small, set of primes. Bailey's grammatical system is similar to Saussure's (1962) where "tout se tient"—it all hangs together.

Chapter 3 applies modern linguistics concept and devices to the construction of grammars. These include: (i) writing the formal empty form *e* to replace deleted forms—making grammatical phenomena more transparent and intelligible—as well as the use of generative linguistic concepts such as raising and other types of movement (Chomsky, 1981, 1986); (ii) grammatical devices employed in developmental linguistics such as markedness-reversal in marked environments, e.g., reversals in negative contexts with auxiliaries, modals, passives, etc. (Bailey, 1984; Faingold, 1991); and (iii) Labov's (1978: Chapter 8) observer's paradox, showing that speakers who deny using get-passives, as well as other structures, do in fact produce these forms in unmonitored speech.

Chapter 4 discusses the issue of grammatical correctness in the English-speaking world and elsewhere. As Bailey shows, grammatical correctness in English is determined by fashionable (typically young) speakers, while other countries (e.g., Spain, France, Germany) have language academies or other authorities who determine the grammaticality of language structures. English dictionaries are replete with "errors" because they record, rather than define, what is acceptable; in contrast, the dictionaries produced by language academies or other authorities are by definition free of errors because they legally define language form.

The appendix defines Bailey's use of concepts such as modal verbs, verbids, aspectuality, modality, and marke(re)dness.

WMEIWMBG makes an invaluable contribution to the teaching of English grammar. It applies modern linguistic models, reduces terminological and structural chaos, and provides a systematic analysis of a wide range of phenomena. Specifically, (i) spurious grammatical categories (e.g., adverbial nouns, pronominal demonstratives, the "genitive" case, etc.) are reduced to the recognized parts of speech based on the more fundamental

grammatical categories of case, predication, and modification with apposition; (ii) current categories such as subjunctives are seen as processual modalities, anteriors as distinct from perfects, and timeless verbal forms (e.g., present perfect) as separate from real presents (e.g., present continuous); and (iii) seemingly chaotic patterns of the English verb are systematically handled with developmental devices such as markedness-reversal--whereby systematic and predictable reversals occur in marked categories and environments (e.g., in timeless, anterior, posterior quasi-temporal categories, and modals under negation, interrogation, and comparison).

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Dr. Eduardo Faingold is an adjunct professor of Hebrew and a visiting scholar in the Department of Linguistics at the State University of New York at Stony Brook. He received his undergraduate degrees at the Hebrew University of Jerusalem in English linguistics and French language and literature, and did graduate studies in English and general linguistics at the Hebrew University of Jerusalem, the Technische Universitat Berlin, and Tel-Aviv University. Faingold has been a visiting scholar at the Institut fur Linguistik of the Technische Universitat Berlin and the Department of TESL/Applied Linguistics of the University of California, Los Angeles.

An Introduction to Second Language Acquisition Research by Diane Larsen-Freeman and Michael H. Long. London and New York: Longman, 1991. xvii + 398 pp.

Reviewed by
Charlene G. Polio
Michigan State University

Over the past few years, applied linguistics has been trying to answer the question: what is applied linguistics? (See discussions on this question in *Issues in Applied Linguistics*, 1990, 1992.) Second language acquisition (SLA) has avoided the potentially polemic question: what is SLA? While there is little doubt that SLA is a field in its own right (see Gass, in press; Larsen-Freeman, 1991), what constitutes mainstream SLA, or the core of the field, may not be agreed upon. As the field grows and fragments, this issue needs to be addressed. Nowhere is the issue of defining the field of SLA as pertinent as in the writing of an introductory SLA textbook. Ten years ago, such a task would not have been as formidable. Today, one must first ask what should be included and in what depth should it be covered?

The most recent effort to introduce newcomers to the field of SLA is Larsen-Freeman and Long's *Introduction to Second Language Acquisition Research*. In evaluating such an effort, one must consider what the authors chose to include and what to exclude. Were any essential research or concepts omitted and/or was any research on the fringes made to seem part of the field? Will students who use this book have a perspective, consistent with others in the field, on what SLA is? Have the authors fulfilled their responsibility to those using the book to present a balanced view of a field that is fast finding researchers disagreeing on basic issues and theoretical frameworks? I believe that Larsen-Freeman and Long's book can be evaluated quite positively with regard to these questions. A summary of the book, with attention to these issues, follows.

The book consists of eight chapters. The first is a lucid introduction, explaining, very briefly, what the field is and that, while teachers' expectations from SLA must, at this point, be "modest" (p. 3), there is some relation to language teaching. They take an appropriate middle ground, saying neither that SLA research must serve only to benefit language teaching, nor that those ties should be severed (see Newmeyer and Weinberger, 1988 for this latter view).

The second chapter discusses research methodology, including characteristics of both qualitative and quantitative research, in a manner accessible to new students of SLA. The authors are fair to both sides, showing which paradigms can be used for which purposes. Of the qualitative and quantitative paradigms, they say, "Rather than seeing them as competing paradigms, we see them as complementary, implying that it is unnecessary to choose between the two" (p. 24). They also discuss different types of data collection without advocating one over the other.

The third chapter provides a historical view of methods of analysis in the field of SLA. In a field that is only 20 years old, it is appropriate to provide a comprehensive history, particularly for students to see how the field evolved and to keep them from repeating past errors. In keeping with trends in the field, they appropriately criticize contrastive analysis, error analysis, and morpheme acquisition studies. They say that discourse analysis (very broadly defined) has subsumed previous methods of analysis. While this is true in relation to the other methods of analysis discussed, those working in a Universal Grammar (UG) framework might take issue with this characterization.

Chapters four, five, and six deal comprehensively with various findings about interlanguage, the linguistic environment (input and interaction), and explanations for differential success among SLA learners.

Chapter seven is a good introduction to theories and theory construction. The authors begin by comparing the set-of-laws form, and the causal-process form, clearly showing their preference for the latter. At the end of the chapter, they say, without reference to any work, that not all in the field share their views. (For opposition to their view see Klein, 1990 and Markee, 1991.) They present and critique several theories of SLA, classifying them as nativist, environmentalist, or interactionist. Any book claiming to be an introduction to the field cannot ignore the fact there is no consensus on SLA theory and thus Larsen-Freeman and Long state at the end of the chapter:

The rise of a single dominant theory which discourages competing points of view, given our present limited state of understanding, would be counter-productive. We must guard against overzealousness on the part of theorists or their devotees who feel that they have a monopoly on the truth. While SLA research and language teaching will benefit from the advantages of theoretically motivated research which

we have spelled out in this chapter, it would be dangerous at this stage for one theory to become omnipotent. (p. 290)

Even Beretta (1991), who argues that multiple theories are problematic for SLA, states that it is not necessary "for theory choice to be made *now*" [emphasis in original] (p. 507). And as the choice has not yet been made, it is essential to provide students of SLA with all possible theories.

The book ends with a chapter on instructed SLA, showing that the authors are truly concerned with the relationship between instruction and SLA. Research on, for example, how instruction does or does not affect developmental sequences should be of interest to any student or researcher of SLA, not only to language teachers.

Despite the fact that the authors' biases can often be seen throughout the book, they clearly try to present all sides of issues and at times explicitly state their biases. Furthermore, they include work which has become part of SLA that they themselves have not been active in (e.g., UG, connectionism). Larsen-Freeman and Long admit that they have omitted work on lexical acquisition and pragmatics. Also missing is much reference to cognitive theory including issues such as restructuring and automaticity. Furthermore, Larsen-Freeman and Long, with one notable exception, do not overemphasize issues in SLA that are not mainstream. The exception is the 18 pages devoted to the Multidimensional Model of SLA. Although worth including, particularly because of its potential application to cross-linguistic SLA research, I doubt it is as widely-cited as Larsen-Freeman and Long's book might suggest, at least now. (Other SLA textbooks (Ellis, 1986; McLaughlin, 1987; Gass and Selinker, in press) give it little or no attention at all.) Nevertheless, this book is, without a doubt, the most comprehensive review of SLA research to date. It is extremely dense, but in a classroom setting beginning students of SLA with a background in linguistics should find it accessible.

With regard to the book's format, at the end of each chapter there are excellent comprehension and application activities. The lack of an author index is, however, extremely frustrating. Upon finding an interesting reference in the bibliography, one has no way to find out where in the book an author's work is cited, thus hindering its use as a reference.

Earlier I mentioned the authors' responsibilities to present a balanced view of the field. While one may not agree that such a responsibility exists, one cannot argue with the fact that an

introductory text with two such notable authors will be widely used. I believe that instructors using the book can feel confident that their students will have a balanced mainstream view of the core issues in SLA.

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Charlene Polio recently completed her dissertation on the acquisition of Chinese as a second language at UCLA. She is now an assistant professor in the Department of English at Michigan State University.

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Communication Strategies: A Psychological Analysis of Second-Language Use by Ellen Bialystok. Applied Linguistics Series, D. Crystal and K. Johnson, Eds., Cambridge, MA.: Basil Blackwell, 1990. vi + 163 pp.

Reviewed by
James E. Purpura
University of California, Los Angeles

Over the past fifteen years, there has been an increased interest in the cognitive processes which account for how the learner of a second language (L2) handles conceptual and linguistic input, how this learner processes this information to allow for intake, and how the newly-acquired knowledge is used to produce messages in the L2. Second-language learning strategy research focuses on the processes and strategies used to perceive, internalize and automatize new linguistic input, with emphasis on language learning. Bialystok's work, *Communication Strategies*, however, differs from other books on strategy research (O'Malley & Chamot, 1990; Oxford, 1990; Wenden, 1991) in that it takes a much narrower focus, concentrating on the processes and strategies a learner invokes when declarative and procedural knowledge are utilized to communicate a message. The emphasis of this book is on language use and the linguistic and cognitive processes involved in communication. Thus, in providing an in depth analysis of the processes and strategies used in language production, *Communication Strategies* provides a unique contribution to learning strategy research.

Bialystok's overall goal in *Communication Strategies* is "to find a means of explaining how strategies function in the speech of L2 learners" (p.13). The book contains a preface, eight chapters, notes, references and an index. In Chapter 1 Bialystok finds all the definitions of communication strategies commonly used in strategy research to be ambiguous. Bialystok also criticizes, although not explicitly, the undue emphasis in strategy research on definitions and proposes an approach to investigating communication strategies which fully incorporates the identification, explanation, and instruction of communication strategies. The remaining chapters of the book are organized around these three points. Chapters 2, 3, and 4 address the question of how to identify and categorize strategic behavior in the communication of L2 learners. Chapters 5,

6, and 7 explain the processes involved in L1 and L2 acquisition and use and propose a framework for language processing. Finally, Chapter 8 discusses the pedagogical issues related to communication strategy instruction.

In Chapter 1 Bialystok criticizes the definitions of communication strategies used by researchers for their focus on the features of problematicity, consciousness and intentionality. In her treatment of these definitions, she highlights their ambiguous nature such as the fact that (1) learners use communication strategies not only in problematic situations, but in non-problematic situations as well; (2) learners might or might not use these strategies consciously; and (3) these strategies could be invoked with any degree of intentionality to achieve specific communicative goals. Instead, Bialystok recommends that we investigate the strategy use by determining a means to identify and explain strategic behaviors and by assessing the teachability of these strategies for purposes of facilitating more effective language learning.

Chapter 2 examines different ways of identifying strategic behaviors and attempts to clarify the psychological construct of communication strategy. In this chapter, Bialystok situates communication strategies within the framework of language use, but unfortunately makes no attempt to relate language use to a more general model of communicative competence. Rather, she briefly describes a hierarchical structure where language use is divided into processes and strategies and where strategies are further subdivided into communication and learning strategies. She first discusses the distinction between strategies and processes and concludes that "without substantial direction in how to proceed with a distinction between strategies and process of language production, the possibility that these are ultimately not different events remains tenable" (p. 25). She then attempts to differentiate communication strategies from other types of strategies (e.g., production strategies (Tarone, 1980), learning strategies (Stern, 1983), and social strategies (Wong Fillmore, 1979). Bialystok reports on a third attempt to identify strategic behaviors in communication which arises from the investigation of systematic differences among speakers engaged in different types of communication. Here the manipulation of messages and linguistic forms is studied to determine to what extent an original message was reduced, deleted, altered, or avoided. I found Bialystok's attempt to delineate language use in this chapter somewhat ambiguous. The language use hierarchy upon which the chapter was based seems to be inspired by disparate theoretical arguments explaining the construct

of communication strategies and, in my opinion, the chapter raises more questions than it answers.

In Chapter 3 Bialystok provides a comprehensive summary of the major taxonomies used to classify communication strategies (Tarone, 1977; Varadi, 1980; Bialystok & Frohlich, 1980; Faerch & Kasper, 1983; Paribakht, 1985). Bialystok notes that researchers seem to agree on the communicative behaviors used by L2 learner but asserts that no single specific factor seems to predict the use of any one strategy. The potential of these taxonomies to describe strategies is then evaluated in Chapter 4. Here, the author reports on a study of the strategic behaviors of 18 nine-year-old English-speaking children learning French. Tarone's taxonomy was used in this study and Bialystok states that the criteria used to classify strategic categories were sometimes ambiguous and arbitrary. In Chapters 3 and 4, Bialystok provides a convincing and insightful argument illustrating the potential shortcomings of existing taxonomies, and rightfully concludes that instead of studying strategies independently through definitions or taxonomies, strategies should be analyzed within a coherent model of speech production.

In Chapter 5 Bialystok surveys the research on child and adult strategy use in L1 production and compares this to adult strategy use in L2 speech. She maintains that the communication problems faced by children in early phases of acquisition are similar to those encountered by L2 learners and remarks that aside from the adult's cognitive conceptual maturity and access to a developed lexicon in another language, the strategies used by children and adults are identical. This point, however, seems debatable, if for no other reason than the comparatively greater variety of strategies used by adults and the flexibility with which they use them. Furthermore, this assertion contradicts previous work by Brown, Bransford, Ferrara, and Campione (1983) who claim that strategic behavior develops with age. Nonetheless, this point presents an interesting line of future research to pursue. Finally, Bialystok adds that "there is no doubt that adults use these strategies more effectively, more efficiently and more flexibly than children do, but there is no evidence that the strategies themselves are any different" (p.101).

In Chapter 6 Bialystok reviews two studies focusing on children and adults' use of an L2. These studies, she claims, differ from previous ones in that "the classification [of the L2 utterances] is based on distinctions between processes" (p. 104). This reference to "process," however, is the source of considerable confusion as it is not defined. The only apparent difference between

these studies and the previous ones is that the classifications in the current studies are not solely generated from observable utterances, but are structured to require the children to process information on a metalinguistic level before attempting a task. For example, the first study investigates the ability of children to construct formal definitions. Snow and her colleagues (1989) chose this task because it provided a "decontextualized metalinguistic use of language" as a process. They found that children could identify and construct formal definitions as early as age 7. The second study examined how adults use referential strategies in both their L1 and their L2. The classification of the utterances in this study was organized according to the production processes speakers use. The taxonomy emerging from this study consisted of conceptual and linguistic strategies. The conceptual strategies involved approximation and circumlocution strategies, while the linguistic strategies involved borrowing, foreignization, transliteration, and word coinages. I felt that Chapters 5 and 6 accurately illustrated the need to go beyond research based on definitions or taxonomies and demonstrated the explanatory potential of communication strategy research based on a model of language production as well as on the definitions and taxonomies.

Bialystok describes her theoretical model of language acquisition and processing in Chapter 7. In this framework language proficiency consists of two components of language processing: the analysis of linguistic knowledge and the control of linguistic processing. The analysis component refers to how language knowledge is represented and accessed, while the control component deals with the executive procedures for performance. Bialystok applies this framework to communication strategies, stating that the analysis-based strategy allows the L2 learner to examine and shape intended meaning, while the control-based strategy permits the speaker to focus on linguistic form or some other source of information. I felt that this framework clearly illustrates the dynamic interaction between these two components because it reflects the ways all people process language production when communication requires extension or adaptation. In the case of children or L2 learners, this production system is often strained due to an inability to adjust to the communicative event.

Chapter 8 superficially discusses the potential value of learning and teaching communication strategies. Bialystok presents a strong view of instruction which maintains that taxonomic listings can be taught explicitly. In other words, learners can be taught to paraphrase, to invent new words, and the like. She also discusses

the moderate view which states that strategies can be presented as devices to be used in solving communication problems. I felt, however, that perhaps a more realistic approach to learning and teaching communication strategies would involve the combination of both views in accordance with the changing situational demands of the syllabus.

In sum, despite its shortcomings, *Communication Strategies* is an inspiring book for applied linguists who wish to pursue research in learning or language use strategies. It provides a critical analysis of research approaches used thus far in investigating communication strategies and proposes new avenues for further research by means of an articulated cognitive component. I found this book to be challenging in places, but a very informative read indeed. *Communication Strategies* is an essential source for those seeking an orientation to the current issues in learner strategies.

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James E. Purpura is a Ph.D. student in Applied Linguistics at the University of California, Los Angeles. His research interests include language learning and test-taking strategies.

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Syntax: A Functional-Typological Introduction II

by Talmy Givón. Philadelphia: John Benjamins 1990.

Reviewed by

Howard Williams

University of California, Los Angeles

Syntax: Volume II is the second book in Givón's two-volume morphological and syntactic survey of language from a functional perspective. (For a review of the first volume, see Heath, 1986) As a functionally-oriented grammarian, Givón concerns himself not with formal syntax but with the systematic uses to which constructions are put. Syntax is for him functional in a strong sense: the form of language is claimed to be a direct reflection of users' communicative needs at all levels of analysis. While the heavily English-oriented second volume may be read independently of the first, some grounding is in order. For Givón, the levels of analysis appropriate to syntax are the discourse-pragmatic, the propositional-semantic, the lexical-semantic and the phrasal-semantic; the four have individual requirements which occasionally conflict. To understand syntax is to understand these levels and the conflicts among them. Knowledge of diachronic change is also essential to a proper understanding of structure.

Chapter 12, the opening chapter, deals with the coherence of noun phrases (NPs). The order of pre- and post-nominal modifiers is held to be determined on a scale of relevance as in Bybee (1985); there is a partial parallel to the placement of complements and adjuncts in formal approaches. Elements of NPs tend to be contiguous rather than scattered through a clause for iconic reasons, to preserve functional unity. Conjunction of NPs is limited to NPs of equal thematic status with similar case roles. "Separate events will tend to be encoded by separate clauses" (p. 488); a fairly detailed section illustrates the "pragmatic-cognitive" difficulties of this phenomenon. In a section on nominalization of clauses, a scalar order of nominal-like phrases is presented, with *for-to* clauses at the bottom and the *enemy's destruction of the city*-type nominals at the top. Exactly what this would mean in syntactic terms (e.g., the inability of infinitives to serve well as the subjects of yes-no questions) is not addressed.

Chapter 13 deals with verbal complementation, investigating the semantic nature of the relationship between main and embedded

clauses. The chapter illustrates what are seen as weaker semantic bonds with cognition-utterance ('know') verbs compared to the successively tighter bonds with manipulative ('order') and temporal aspect ('finish') types. The relative strength of bond is reflected in the syntax, attesting to the latter's iconicity. The more loosely bound a main verb is to its dependent clause, the more likely the presence of a complementizer; how this squares with missing 'that' in English bridge clauses (*I said he's here*) is unclear.

Chapter 14 covers voice and detransitivization. A systematic comparison is made of active/passive/antipassive/reflexive with regard to topicality, case marking, promotion, and demotion. The need for semantic marking of passive topics conflicts with the requirement for pragmatic marking, creating a 'functional bind' for the morphology; this bind is treated in greater detail in Volume I.

Most types of relative clauses are treated in Chapter 15. Restrictives and nonrestrictives are contrasted with respect to their position in the higher clause, marking of verbal elements, use of relative pronouns, presence of gaps vs. resumptives, and word order. Sections on clausal extraposition, the Complex Noun Phrase Constraint (CNPC), and center embedding underscore the gulf between the formal approaches and Givon's functional approach: the CNPC is seen here as a limit which is probably based on physical distance rather than on constituent structure alone (cf. Newmeyer's (1983) discussion of Givón (1979) on this point).

The next two chapters treat contrastive focus and marked topic constructions. Much space is devoted to illustrating what is presented at the end of Chapter 16 as the "preposed order principle," according to which less predictable but more important information is viewed as "more likely to be placed earlier in the clause" when placed in the context of precessing and memory (p. 737). Exceptions (such as pseudoclefted NPs and determiner-noun order) abound, but are not addressed as counterexamples. In a natural continuation, Chapter 17 deals with marked topics including shifted datives (viewed as topic promotions) and raising constructions. Raising to object, now a relic in generative theory, is argued also to be a case of topic promotion. Without a true raising rule, however, the chameleon-like nature of belief-type objects could be reinterpreted as a case of closer event integration of the lower with the higher clause.

Chapter 18 is an overly cursory treatment of non-declarative sentence types. These types are, as often is the case with types in Givon's work, placed on a continuum with prototype peaks.

The lengthy Chapter 19, "Interclausal Coherence," covers the relations between adverbial and main clauses, coordinate clauses, and larger discourse units. The links among such units are argued to be looser than those between main and complement clauses. Semantic evidence is a greater freedom to break continuity links; syntactic evidence lies in intonational contours and the ability of adverb clauses to prepose, thereby effecting higher topical status. Participial clauses are seen as more or less integrated, depending on their type. Introducing yet another scale, Givón redefines "finite" as a complex of features including tense-aspect-modality, agreement, and other (including nominal) affixes. There is also a long section on clause-chaining and typology.

Chapter 20, "The Grammar of Referential Coherence: A Cognitive Reinterpretation," might have been more fitting as an opening chapter of the book. Grammar is reinterpreted "as mental processing instructions" (p. 894) and Givón promises testable hypotheses based on domains outside grammar, though we are largely left without a clear means to test for the derivative status of grammar. The "mental proposition" is the basic unit of stored information, but since discourse is multi-propositional and shared, grounding is necessary. New propositions are viewed as a felicitous combination of old and new information, with the former serving to ground and the latter serving to move the discourse along. Grounding is based in grammatical devices which code referentiality and definiteness; thematic coherence across clauses is established primarily by the "grammar of topicality" (the establishment of topics using mainly nominal arguments as signals). "Coherent discourse is characterized by equi-topic clause chains" (p. 902). There is an attempt to underpin the notion of referential coherence in cognitive terms; definite vs. indefinite NPs and lexical vs. pronominal NPs are reinterpreted in terms of "active vs. existing memory files" and "short- vs. long-term memory searches."

The final chapter explores the concepts of markedness and iconicity in syntax. Markedness is seen as a function not only of relative structural complexity and frequency but also of cognitive complexity, the last being defined in terms of "attention, mental effort or processing time" (p. 947). Canonical declaratives are seen as the unmarked type; the prevalence of non-declarative manipulatives in early child speech is seen as an evolutionary throwback to stages when such clauses were unmarked. Markedness scales for nouns and verbs with respect to affixes and referentiality are a carryover from Givón's longer treatments in Volume I.

Autonomous syntax is here repudiated much as it is in Givón 1984. Three "iconic coding principles" are set, two of them clearly morphosyntactic. The "quantity principle" gives the larger, less predictable, and more important information a larger "chunk of code" or more "coding material" (969). How the terms '*important*' and '*predictable*' are operationally defined and how the three might be collectively measured in their interaction is not explained. The "proximity principle" places "functionally, conceptually, or cognitively" similar "entitites" closer together in the sentence, as evidenced in the relative syntactic integration of two clauses (cf. Chapter 13) and the relatively non-scattered nature of elements of phrases within clauses (cf. Chapter 12). The "linear order principle" places clauses in connected discourse in sequential order in unmarked cases. What is non-iconic in syntax is held to combine with the iconic so as to "reinforce" the latter. In the final section, there is an attempt to ground iconicity in biology with arguments from genetics and animal communication.

In a general way, the sequencing from the beginning of the first volume to the end of the second involves a movement from smaller-scale phenomena (e.g., case marking, tense-aspect-modality, agreement) to large units of language that extend beyond syntax in the usual sense. As the sequence proceeds, the case for a functional approach seems to grow roughly with the size of the unit examined. The larger the unit, the more the syntactic choices for the user of language, and where genuine options exist, the investigator can study the contexts for the choices. Givón is at his most plausible in reporting the high likelihood of referential continuity across *and*-clauses as compared to *but*-clauses (Chapter 19) or on the pragmatics of marked topic constructions, where a systematic comparison of discourse anaphors, dislocated and other NPs is made with regard to referential distance from like material. The repeated references to the fact that speakers make syntactic choices rings far truer here than in Volume I, where the more basic elements of syntax discussed are simply given by the grammar; one can reasonably choose to cleft, but one cannot dictate the form a cleft will take. Here the two senses of functionalism are confused: one is the functionalism of day-to-day usage, the other the alleged functionalism of linguistic evolution. It is possible to accept the one without completely accepting the other.

If this volume (and the first) purported to be concerned with the discourse functions of syntactic constructions, it would be easier to accept on the whole. The fact that it attempts to treat syntax as an essentially discourse-grounded phenomenon makes it harder to

accept. Formal relations are a ghost in Givón's machine; yet the existence of formal, less plainly iconic phenomena is implicitly suggested throughout the book. If *She is believed to be a crook* is an example of topic promotion from the embedded clause, then **She is believed [] is a crook* ought also to be possible; it is not, but in this framework we have no apparent means of determining why. The fact that that clauses are less referentially integrated than infinitives does not really solve the problem because one may topicalize from either an infinitive or a complement clause. Similarly, Givón's pervasive use of scalarity would seem to predict more of a continuum of word order possibilities than actually exists; focusing may be an initial (*Him I dislike*), medial (*It's him I dislike*), or final (*I dislike him, but I like her*) option, but the medial **I him dislike* is disallowed for unexplained reasons. Surely such a sentence is more than merely pragmatically inefficient. In the first volume constraints are said to exist (1984: 36), but it is not clear that they are ever explicitly elaborated. In fact, we do not know exactly what they are constraints on. In general, we do not learn how functional considerations alone can really predict the form that a given language will take or be prevented from taking.

The term "functional grammar" means different things to different people. (For a review of these different meanings, see Tomlin 1990.) If researchers seek correlations between particular structural types and particular discourse functions, that is a relatively modest goal. If one seeks to render formal syntactic theory superfluous, that is a much more ambitious goal, and one which may not be feasible (cf. Newmeyer 1983: 119ff.). At any rate, one needs a fully developed theory of discourse requirements which exists independently of grammar, as well as a method of mapping function onto structure, and a means of accounting for counterexamples, in order to successfully derive syntax from the theory. An attempt to show that a specific construction is configured in a particular way simply because that is the most functional way for it to be configured must show independently that some other arrangement would not be equally functional. In the second-to-last chapter, Givón does actually begin to do this by linking grammar to cognitive principles, but the discussion remains quite speculative.

A more modest goal for a functional grammar is worthy in spite of being modest. It is worthwhile, for example, for second-language teachers to know more than simply how *wh*-clefts are formed; it is worthwhile to know what they do, and for this purpose a functional complement to traditional or formal grammar is useful.

This complement need not seek a discourse function for every aspect of syntactic structure; even if the search were successful, it is not certain what role some facts (e.g., "aspect before tense") could play in teaching. Many of the areas treated in *Syntax: Volume II* do seem relevant in just this respect, in particular speech acts, contrastive focus, interclausal coherence, and generally all areas which deal with topicality. Overall, however, this volume does not quite fit the description of a book fulfilling the more modest goal. Perhaps no existing book does, though Dik (1989) and Halliday (1985) seem to come closer.

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INDEX TO VOLUME 3, 1992

Issues in Applied Linguistics

Authors and Articles

- Clachar, Arlene. (Number 1, June). Dimensions of Locus of Control: Exploring Their Influence on ESL Students' Interlanguage Development. 7-41.
- Haynes, Laurie Ann. (Number 1, June). The Development of Speaking/Writing Variability in Narratives of Non-Native English Speakers. 43-67.
- Lem, Lawrence. (Number 2, December). Beyond Broca's and Wernicke's Areas: An Alternative View on Neurobiology of Language. 213-233.
- Makoni, S.B. (Number 1, June). The Effects of Linguistic Context on Unplanned Discourse: A Study in Interlanguage Variability. 69-90.
- Robbins, Scarlett. (Number 2, December). Procedural Linguistic Skill Acquisition: A Neurobiological Model. 235-265.
- Sato, Edynn & Jacobs, Bob. (Number 2, December). From Input to Intake: Towards a Brain-Based Perspective of Selective Attention. 267-292.
- Shirai, Yasuhiro. (Number 1, June). Conditions on Transfer: A Connectionist Approach. 91-120.
- Wagner, Elaine. (Number 1, June). The Older Second Language Learner: A Bibliographic Essay. 121-128.
- Yoshitomi, Asako. (Number 2, December). Towards a Model of Language Attrition: Neurobiological and Psychological Contributions. 293-318.

Special Feature

- Roundtable. (Number 1, June). Preparing Applied Linguists for the Future. Contributions by: Marianne Celce-Murcia, John H. Schumann, Leslie M. Beebe, Craig Chaudron, Susan M. Gass, Sandra J. Savignon, John J. Staczek, Patricia A. Duff, Rebecca Freeman, Linda Lane, India Plough, Peter J. Robinson, Allison Smith. 131-169.

Exchange.

- Fantuzzi, Cheryl. (Number 2, December). *Connectionism: Explanation or Implementation*. 319-340.

Review Authors

- Celce-Murcia, Marianne. (Number 1, June). *Learning, Keeping, and Using Language: Selected Papers from the 8th World Congress of Applied Linguistics, Sydney, 16-21 August*, by M.A.K. Halliday, John Gibbons, and Howard Nicholas (Eds.). 173-178.
- Faingold, Eduardo D. (Number 2, December). *Why More English Instruction Won't Mean Better Grammar*, by Charles James N. Bailey. 341-343.

- Kunnan, Anthony John. (Number 1, June). *Multilingualism in India*, by Debi Prasanna Pattanayak (Ed.). 179-184.
- Polio, Charlene G. *An Introduction to Second Language Acquisition Research* by Diane Larsen-Freeman and Michael H. Long. 344-347.
- Purpura, James E. (Number 2, December). *Communication Strategies: A Psychological Analysis of Second-Language Use*, by Ellen Bialystok. 348-353.
- Williams, Howard. (Number 2, December). *Syntax: A Functional-Typological Introduction II* by Talmy Givon. 354-359.

Authors of Publications Reviewed

- Bailey, Charles James N. (Number 2, December). *Why More English Instruction Won't Mean Better Grammar*
- Bialystok, Ellen. (Number 2, December). *Communication Strategies: A Psychological Analysis of Second-Language Use*.
- Gibbons, John. (See Halliday, Gibbons, & Nicholas).
- Givon, Talmy. (Number 2, December). *Syntax: A Functional-Typological Introduction II*
- Halliday, M.A.K., John Gibbons, and Howard Nicholas, (Eds.). (Number 1, June). *Learning, Keeping, and Using Language: Selected Papers from the 8th World Congress of Applied Linguistics, Sydney, 16-21 August*. 173-178.
- Larsen-Freeman, Diane and Michael H. Long. (Number 2, December). *An Introduction to Second Language Acquisition Research*
- Nicholas, Howard. (See Halliday, Gibbons, & Nicholas).
- Pattanayak, Debi Prasanna (Ed.) (Number 1, June). *Multilingualism in India*. 179-184.

Editorials

- Jacoby, Sally. (Number 1, June). *Interlanguage and Interregnum*. 1-6.
- Plummer, Joseph R. (Number 2, December). *On Neurons and Other Embarkations*. 203-208.
- Schumann, John H. (Number 2, December) *Exploring Neurobiology of Language*. 209-212.

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